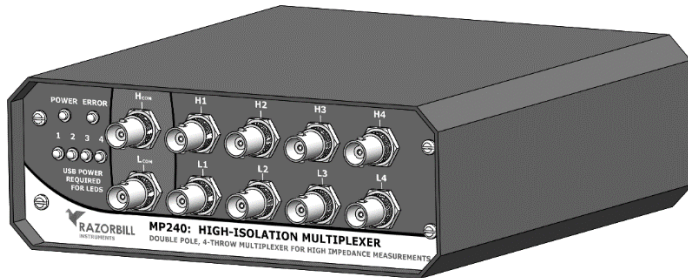


# MP240 Manual

Multiplexer for capacitance measurements



The MP240 is a double pole, quad throw fully shielded coaxial multiplexer designed for use in high impedance measurement systems.

This multiplexer can be used in conjunction with other Razorbill Instruments products, it is ideal for use with devices such as the UC200 that contain more than one capacitive sensor, or in cases where more than one stress or strain cell is used simultaneously.

The MP240 may be controlled by USB or by a digital input. The digital input is compatible with Andeen-Hagerling capacitance bridges.

## Scope of use

The multiplexer is intended to be used by research scientists and trained laboratory users, not household consumers. Consequently, some basic understanding of the conventions regarding the use of sensitive laboratory equipment is assumed.

This document is designed to allow the end-users to safely and efficiently set-up and operate the MP240 High Isolation Multiplexer and use it in conjunction with other Razorbill Instruments products. The document is also designed to draw attention to any risks and hazards involved in operating the MP240 and the steps necessary to minimise them.

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<b>Size</b>	Length	180 mm
	Width	185 mm
	Height	65 mm
	Weight	approx. 1.2kg
<b>Power supply</b>	USB operation	5 V, 200 mA
	Digital Input Port	5V, 100 mA
<b>Switched Signal</b>	Max voltage	30 V
	Recommended current	< 10 mA
	Max switching current	400 mA
	Max carrying current <sup>1</sup>	1000 mA
<b>Switching behaviour</b>	order	Break before make, 3 ms typ.
	topology	Double pole quad throw, or as independent relays (USB control only). Unconnected outputs are grounded
	Max switching speed	5 s <sup>-1</sup>
	Switching cycles	> 10 <sup>6</sup> at maximum current > 10 <sup>8</sup> at recommended current
<b>Isolation</b>	Typical use case <sup>2</sup>	<2 aF
<b>Connectors</b>	Switched signals	BNC
	USB	USB-B
	Digital input	D Sub 15
	Ground	4mm plug, fork, or bare wire
<b>Materials</b>	Enclosure	Powder coated aluminium
	Front and rear panels	Printed aluminium

See also: Electrical specifications of the digital input port on page 19

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<sup>1</sup> The multiplexer must not be switched when the max switching current is exceeded

<sup>2</sup> When the multiplexer is used with an AH2550 capacitance bridge to measure a capacitance of 1 pF, changing the adjacent channel from <10aF to 100nF causes a spurious change of less than (0.3+2i)aF on the 1pF measurement.

## EU Declaration of Conformity

<b>Product Name</b>	High Isolation Multiplexer
<b>Model Number</b>	MP240
<b>Manufacturer</b>	Razorbill Instruments Ltd
<b>Manufacturer's Address</b>	Unit 8, Castlebrae Business centre Peffer Place, Edinburgh EH16 4BB, UK
<b>Authorised Representative in the European Union</b>	24hour-AR Van Nelleweg 1 3044 BC Rotterdam The Netherlands

This declaration of conformity is issued under the sole responsibility of the manufacturer. The object of the declaration (described above) is in conformity with the following European directives:

2014/30/EU	EMC directive
2011/65/EU	RoHS directive

And has been tested according to the following standards:

EN61326-1:2013
----------------

Signed for and on behalf of Razorbill Instruments:




Dr Alex Ward  
Managing Director

Issued on 19<sup>th</sup> May 2022 in Edinburgh, UK.



## UK Declaration of Conformity

<b>Product Name</b>	High Isolation Multiplexer
<b>Model Number</b>	MP240
<b>Manufacturer</b>	Razorbill Instruments Ltd
<b>Manufacturer's Address</b>	Unit 8, Castlebrae Business centre Peffer Place, Edinburgh EH16 4BB, UK
<b>UKCA Mark</b>	

This declaration of conformity is issued under the sole responsibility of the manufacturer. The object of the declaration described above is in conformity with relevant statutory requirements:

Electromagnetic Compatibility Regulations 2016
--

Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment Regulations 2012
---

And has been tested according to the following standards:

BS61326-1:2013
----------------

Signed for and on behalf of Razorbill Instruments:



Dr Alex Ward  
Managing Director

Issued on 1st April 2022 in Edinburgh, UK.

# Supplier's Declaration of Conformity (USA)

This Declaration of Conformity is hereby issued according to Chapter 1, Subpart A, Part 2 of Title 47 of the Code of Federal Regulations by:

Razorbill Instruments Ltd  
Unit 8, Castlebrae Business centre  
40 Peffer Place, Edinburgh  
EH16 4BB

MP240 High Isolation Multiplexer complies with the applicable requirements of FCC Rule Part 18

RESPONSIBLE PARTY located in the United States:

Testing Partners LLC  
18200 SR 306  
Chagrin Falls, OH 44023  
info@testingpartners.com

The responsible party warrants that each unit of equipment marketed under this Declaration of Conformity will be identical to the unit tested and found acceptable with the standards and that the records maintained by the responsible party continue to reflect the equipment being produced under such Supplier's Declaration of Conformity continue to comply within the variation that can be expected due to quantity production and testing on a statistical basis.

(signed)



By: Dr A. Ward

Date: 21-01-21



## Disposing of your MP240

As an electrical good, the MP240 must not be thrown away in normal waste disposal for environmental and ecological reasons.



For products sold to and owned by institutions based within the EU or UK, Razorbill Instruments will be happy to arrange for this product to be picked up and disposed of properly at the end of this products life. This is providing that the product has not been disassembled or contaminated. This is part of Razorbills commitment to the Waste Electrical and Electronic Equipment (WEEE) Directive of the European Community and the corresponding national laws.

For products outside the EU or UK, please dispose of the product using a specialised waste recovery, not in ordinary commercial or household waste.



## Suitable Operating Environments

The MP240 multiplexer must only be used under the following operating conditions

- Indoor use only
- Ambient temperature 5°C - 40°C
- Humidity < 80 % (non-condensing)

## Operating Modes

The MP240 has three operating modes, which are determined by which cables are connected to the rear panel:

- ✦ **USB Only.** The Multiplexer will start in this mode if a USB cable is connected. The microcontroller is running and controls both the multiplexer functionality and the front panel LEDs. Power for the microcontroller is drawn from USB. Power for the relays is drawn from the digital input port if available, or from USB if not. Control signals from the digital input port are ignored. The high and low relay banks can be independently controlled in this mode.
- ✦ **Digital Input Only.** The multiplexer will be in this mode if a digital input cable is connected, but USB is not. The multiplexer functionality is directly controlled from the input port. The microcontroller does not run, and the front panel LEDs do not function. This mode may slightly improve nose levels compared to the other two. The high and low relay banks will operate congruently in this mode.
- ✦ **Digital Input with USB monitoring.** This mode is set by starting the multiplexer in USB Only mode, then sending a mode-change command by via the USB interface. In this mode, the Digital Input Port controls the relays, while the microcontroller monitors them, operates the LEDs and responds to serial commands. If an attempt is made to operate the relays over USB, the error light will illuminate, and

the command will be ignored. The high and low relay banks will operate congruently in this mode.

## Getting Started

### Reading the Front Panel

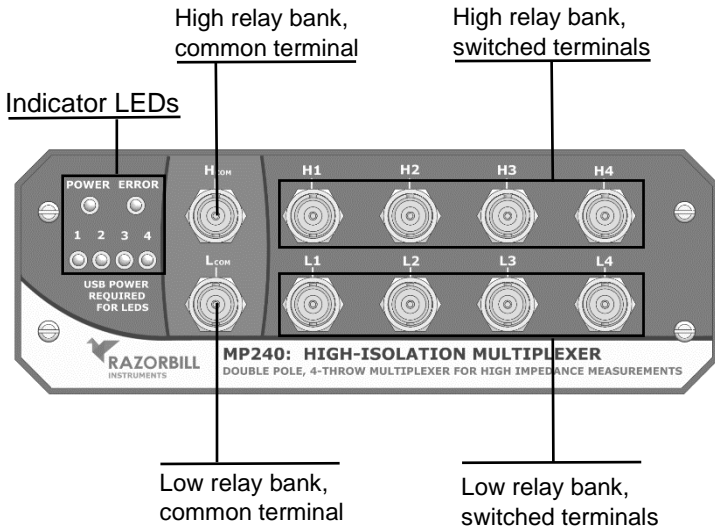



Figure 1: The front panel of the MP240

As the primary mode of control of the multiplexer is using serial commands over a USB connection, the front panel does not feature any input controls and provides only limited information via 6 LED indicators.

#### Indicator LEDs

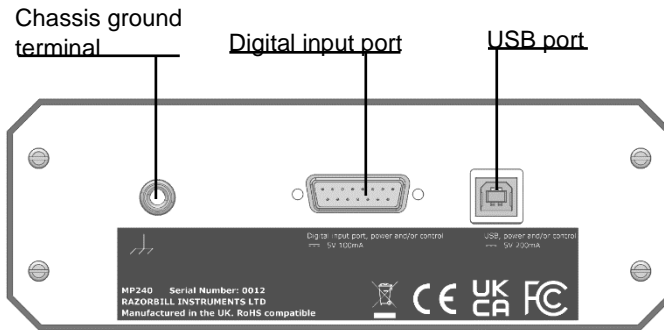
-  **Power LED.** This will show a continuous green light when the control box is drawing power from USB. It does not illuminate when the digital input is used alone.

- ✦ **Error LED.** This light will illuminate red to indicate that an error has been stored. It will go out once that error has been cleared by the PC, or when the device is reset.
- ✦ **Channel Indicators.** When the LED illuminates, the corresponding channel is connected to the COM terminals. When the LED is extinguished, the corresponding channel is connected to ground. If the High and Low relays of a given channel are configured differently, the LED will flash.

## *BNC connectors*

- ✦ **H<sub>com</sub> Terminal.** This BNC terminal is the common connection for the high-side relay bank. It can be connected internally to terminals H<sub>1</sub> to H<sub>4</sub>. This terminal would typically be connected to the output terminal of your measurement device, such as an LCR or Capacitance Bridge. The terminal on the measurement device is typically labelled “high”, “force”, or “excite”
- ✦ **L<sub>com</sub> Terminal.** This BNC terminal is the common connection for the low-side relay bank. It can be connected internally to terminals L<sub>1</sub> to L<sub>4</sub>. This terminal would typically be connected to the input terminal of your measurement device, such as an LCR or Capacitance Bridge. The terminal on the measurement device is typically labelled “low”, “sense”, or “measure”
- ✦ **H<sub>1</sub> to H<sub>4</sub>.** These BNC terminals can be connected to the H<sub>com</sub> by internal relays, and are connected to ground when not connected to H<sub>com</sub>. These would typically be connected to the yellow-marked coax cable on a Razorbill instruments strain cell, or to any other device you wish to measure
- ✦ **L<sub>1</sub> to L<sub>4</sub>.** These BNC terminals can be connected to the L<sub>com</sub> by internal relays, and are connected to ground when not connected to L<sub>com</sub>. These would typically be connected to the black-marked coax cable on a Razorbill instruments strain cell, or to any other device you wish to measure

## Back Panel Layout



*Figure 2: Back panel layout*

- USB Port.** A type B USB port. To use the Multiplexer in USB mode, or digital input mode with USB monitoring, connect a USB cable from the PC to this port. If you wish to use the multiplexer in digital input mode only, leave the USB port empty. If a USB cable is connected, the multiplexer acts as a bus-powered USB2.0 Full Speed device.
- Digital Input Port.** This 15 pin D-Sub connector can be used to control the multiplexer directly. It is compatible with the “switch” output on Andeen-Hagerling Capacitance bridges. If using the Multiplexer in USB mode, this connector should be left empty.
- Chassis Ground Terminal.** This terminal accepts a 4 mm “banana” plug, bare wire (up to 2.5 mm<sup>2</sup> or 14 AWG), or a fork (6 mm or ¼ in). A clean measurement ground should be connected here. This is particularly important when the multiplexer is used with a laptop, as the USB system may not be connected to ground.
- Compliance Information.** This label displays the statutory compliance information required for sale.

## Typical First Time Set-up

- ✦ Place the MP240 on a flat clean, dry surface.
- ✦ Connect your measurement equipment to the BNC jacks  $H_{com}$  and  $L_{com}$ .
- ✦ Connect the first device you wish to measure to H1 and L1, connect the next device to H2 and L2, etc
- ✦ Connect the MP240 using the supplied USB cable<sup>3</sup> by plugging into the rear panel USB port and any available USB port on the PC.
- ✦ Install the correct drivers onto an available computer terminal to be used as the control PC. The drivers are available on the Razorbill Instruments website.
- ✦ The control PC should register the MP240 as a connected device. It will appear as a virtual serial port.
- ✦ The MP240 is now ready to use. It will receive and execute the SCPI commands defined in this document.

## Use with Andeen-Hagerling Bridges

When used with a capacitance bridge from Andeen-Hagerling, the USB connection is not required, and noise will be lower if it is not connected. If it is not connected, the front panel LEDs will not illuminate.

The bridge should be configured with an average time of 7 or higher. This triggers a “cold start” which is required if the measured capacitance changes a lot or if the parasitic capacitance

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<sup>3</sup> The supplied cable is good quality and includes EMI suppression ferrites. The MP240 was tested for EMC compliance with this cable and is not guaranteed compliant with other cables.

of the cables changes. In future firmware versions, it is possible that using the sample switch output will trigger a cold start, in which case this will no longer be necessary. Contact Andeen-Hagerling for further details.

## Technical Description

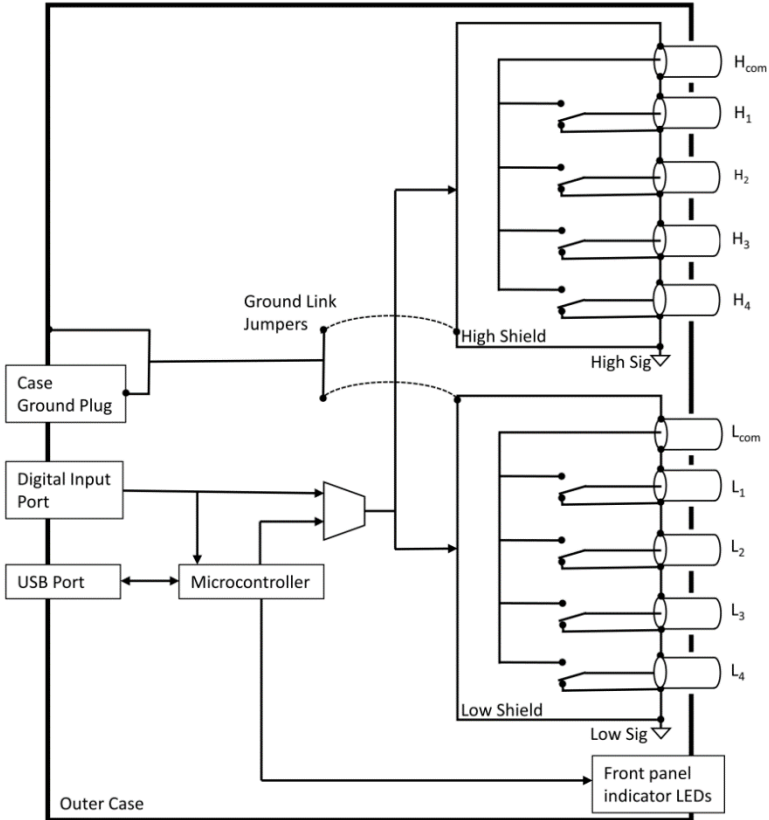
The multiplexer contains two identical relay banks, these are intended simultaneously switch the high and low measurement arms of a capacitance bridge, LCR or similar measurement instrument. Each of these relay banks consists of four BNC connectors that can be either grounded or connected to the COM terminal in the corresponding bank. The layout is illustrated in Figure 3.

## Grounding Notes

The analogue grounds for the High and Low relay banks are internally connected to the case. This arrangement improves electromagnetic emissions and ensures ground is provided to all cable shields irrespective of other attached equipment. When other attached devices also ground the cable shields, there is a possibility of ground loop noise being introduced. Testing with an Andeen Hagerling 2550A in a typical lab environment did not show any reduction in performance with this arrangement, but the analogue grounds have the potential to be isolated from each other and from the case ground should this be necessary. To isolate the analogue grounds, open the upper case and remove the jumper wires from the relay boards to the case<sup>4</sup>. When the jumpers are removed, analogue ground is derived from the shield of the connected cables in each bank.

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<sup>4</sup> The device was tested for FCC, CE and UKCA compliance with the jumpers in place. It is not guaranteed to be compliant without them.



*Figure 3: block diagram*

The case ground is connected to the USB ground and digital input port ground. It is recommended to attach the case ground to a clean ground. This is particularly important if the multiplexer is connected to a laptop or similar portable computer, as these may not provide a ground connection through the USB cable.

## USB Serial communication

The MP240 multiplexer uses a USB virtual serial port to communicate with a computer. The multiplexer acts as a bus-powered USB2.0 full speed device, and requires up to 200 mA from the computer or USB hub to which it is connected. Any

modern PC or powered USB hub will supply this level, but use of unpowered hubs could lead to interruptions, depending on what other devices are attached. You can also use standards-compliant USB extenders. The standard allows for one “dumb” 5 m cable, and up to five “active” extenders or hubs, each adding 5 m of cable.

## *Microsoft Windows*

Razorbill instruments supports the MP240 on Microsoft Windows 7 and higher.

Before using your multiplexer, you should install the necessary drivers for your operating system; these are available on the Razorbill Instruments website. The Multiplexer may work with windows built-in drivers, but our drivers have several advantages including improved reliability of the USB link, and the correct device name appearing in system menus.

When our drivers are installed and the multiplexer is plugged in, a new serial port will appear on your system. Your operating system will normally allow you to set baud rate, stop bits, parity etc. for this port, but as there is no physical serial connection within the multiplexer, these settings have no effect and should be left at the defaults.

Once the virtual serial port has been created, it can be accessed directly as a serial port, or indirectly using, e.g. VISA. Whichever way it is used, you will also need either a terminal emulator to type commands and receive responses, or a program or script to integrate the supply with your measurement system. A basic example using python is included on page 33. Alternatively, Razorbill Instruments can provide a software tool with a basic graphical user interface.



## Linux, Mac OS and other systems

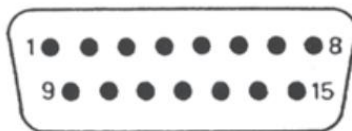
The MP240 implements USB CDC and is likely to work on most modern platforms. We are not able to offer assistance with communications issues on operating systems other than Microsoft Windows.

## Using the digital input port

The Digital input port is designed to be compatible with the sample switch output of Andeen Hagerling capacitance bridges. It can also be used to control the multiplexer from any logic source between 3 V and 25 V.

If power is provided to the multiplexer through the digital input port, this will be used to drive the relays in preference to power derived from USB. This could reduce electrical noise, particularly if the USB system in the computer has deteriorated.

The connector is a standard 15 pin D-Subminiature male socket (with male pins and female screw locks). This is distinct from high density (HD) D-Sub connectors, which have three rows of pins.



*Figure 4: Digital input port pin numbering, view onto mating face of rear panel connector*

## Pin allocations

The pins are numbered according to Figure 4 and the pin numbers are also moulded into the connector. The pin allocations are shown below:

Pin	Function
1	Channel 1 Enable
2	Channel 3 Enable
3	NC
4	NC
5	Ground
6	Power (+5 V)
7	NC
8	NC
9	Channel 2 Enable
10	Channel 4 Enable
11	NC
12	NC
13	NC
14	NC
15	NC
Shell	Ground

*Table 1: Pin assignments for digital input*

### *Enable pins*

The enable pins are active high. When a channel enable pin is driven high, the relevant relays in both the high and low bank will be set to connect the corresponding BNC connector to the COM BNC connector. When a channel enable pin is pulled low or left floating, the corresponding BNC connectors will be connected to ground.

### *Power supply pin*

Pin 6 is intended for use with Andeen Hagerling capacitance bridges, which have a well-regulated 5V output. The power input is only minimally protected and can be damaged by e.g. reverse connection or overvoltage. There is a PTC fuse, if the fuse operates, disconnect the power supply or capacitance bridge. The fuse will automatically reset within a few minutes.

Power supplied to pin 6 from a source other than an Andeen Hagerling capacitance bridge must be well-regulated and should have the minimum practicable noise or ripple. Power supplied in this way will be used to operate the relays. Internal filtering and additional voltage regulation are provided, but there remains some potential for excessive noise on this pin to affect the signal path.



**Warning!** A voltage between 0.2 V and 3.8 V applied to pin 6 when USB power is also connected may damage the multiplexer. Confirm the voltage of the power supply is correct and has sufficient current available to prevent voltage sag.

### Electrical ratings

<b>Channel Enable Pins</b>	Absolute maximum voltage	25 V
	Absolute minimum voltage	-25 V
	High state voltage	> 2.6 V
	Low state voltage	< 0.75 V
	Pull-down	5 k $\Omega$ to ground nominal
<b>Power supply Pin</b>	Absolute maximum voltage	5.5 V
	Minimum functional voltage	4 V
	Recommended voltage	5 V
	Max current draw	100 mA nom. (140 mA fuse)

## SCPI Command Reference

The multiplexer accepts a variety of simple commands, and is designed to comply with the Standard Commands for Programmable Instruments (SCPI) standard. The commands will be described using the following notation:

<b>KEYword</b>	A keyword, which may be written in full or abbreviated to only the letters in capitals. The actual command may use upper or lower case. e.g. the keyword OUTPut means that the commands OUTP, OUTPUT, output and outp can be used and have the same meaning.
[...]	The section enclosed in square brackets is optional
#	The channel to operate on, which may be 1 to 4 inclusive.
<\n>	A terminator. When sending commands to the instrument, CR, LF or CRLF may be used. Responses from the instrument will always end with CRLF.
<bool>	A Boolean option, either 0 or 1. A 1 means true, or enabled, and 0 means false or disabled.
<int>	An integer number, the minimum and maximum will be given in the command description
<other>	Other tokens will be explained in the command description.

Commands fall into two categories. Ones which end in a question mark, and ones which do not. The former are referred to as *queries*. Queries will always generate a response from the instrument and will never have any other effect. Commands which are not queries will never generate a response from the instrument, and generally do have an effect on it.

Normally, individual commands will be sent, each followed by a terminator. However, it is also possible to chain commands with semicolons, e.g.

```
H1 1;H2 1<\n>
```

in which case commands will be executed in order from left to right. When chaining commands, care must be taken that the complete chain, including terminator, is no longer than 255 characters. Otherwise the input buffer will overflow and some of the commands will be lost.

A command which is not recognised by the instrument, is followed by a parameter of the wrong type, or otherwise can't be understood by the instrument will generate an error. Errors are stored in a queue, first in, first out, and while there is something in the queue the error LED on the front panel will be lit. The `SYSTEM:ERROR?` command will fetch to error at the top of the queue, and the `SYSTEM:ERROR:COUNT?` command will return the number of errors present. Note that in some cases, one malformed command can generate several errors.

## Command list

The commands listed here are supported by the 1.0.0 version. Future firmware versions may add more commands and functionality. An up-to-date manual will be made available on the Razorbill Instruments website with each firmware update.

Command	Description	See page
*CLS	System clear	23
*ESE [ ? ]	Error status exe	23
*ESR?	Error status	23
*IDN?	Identification request	24
*OPC [ ? ]	Operation complete?	24
*RST	Reset device	25
*SRE [ ? ]	Service request enable	25
*STB?	Get status byte	26
*TST?	Self test	26
*WAI	Wait for operation	27
SYSTem:ERRor [ :NEXT ] ?	Get last error	28
SYSTem:ERRor:COUNT?	Get number of errors	29
[ROUte]:SELEct #	Set an exclusive route	30
[ROUte]:SELEct?	Check if a route is set	30
[ROUte]:<bank>#	Set an individual relay	31
[ROUte]:<bank>#?	Get the state of an individual relay	31
MODE:EXT	Set serial monitoring mode	32
MODE:EXT?	Check if the device is in serial monitoring mode	32
MODE:PWRSource?	Check if the relays are using external power	32

## SCPI core commands

The commands in this section are required by the SCPI standard, and many of them are implemented purely for compatibility with other SCPI instruments.

<b>*CLS</b>	No response
Description	Clears all status data structures in the device, including all status registers and the error queue.
Example	*CLS

<b>*ESE</b>	No response
<b>*ESE?</b>	<int>
Description	Set or query the Standard Event Status Enable register. This command is required for SCPI compatibility, and is only minimally supported. Refer to the SCPI standard for more information.
Example	*ESE?

<b>*ESR?</b>	<int>
Description	Query the Standard Event Status Register. This command is required for SCPI compatibility, and is only minimally supported. Refer to the SCPI standard for more information.
Example	*ESR?

<b>*IDN?</b>	<str1>,<str2>,<str3>,<str4>
parameter <str1>	The device manufacturer. Always Razorbill
parameter <str2>	The device model. Always MP240
parameter <str3>	The six-digit serial number, as a string, e.g. 000001
parameter <str4>	The firmware version number, e.g. 1.0.0
Description	Query the device identity information. The response is four strings, separated by commas. Almost every SCPI-like instrument supports this command, so it can be used by software to identify the instrument. The firmware number uses the major,minor,release format. Changes to the release version are small bugfixes or changes in packaging and distribution. Changes to the minor version may add features, but will always maintain backwards compatibility. Changes to the major version number may break compatibility.
Example	*IDN?

<b>*OPC</b>	No response
<b>*OPC?</b>	1
Description	The command form sets the operation complete flag. This command is required by the SCPI standard, but has no effect as the flag is always set. The query form queries the operation complete flag, and will always return 1.



Example	*OPC
---------	------

<b>*RST</b>	No Response
Description	On receipt of this command, the device resets to power-on settings. All relays are set to ground, and the device operating mode returns to USB Only. All status registers and the error queue are cleared. The USB serial connection is not reset.
Example	*RST

<b>*SRE</b>	No Response
<b>*SRE?</b>	<bool>
Description	Set or query the service request enable flag. This command is required for SCPI compliance, but even with service requests enabled, the multiplexer will never raise them. So this command has no effect.
Example	*SRE?

<b>*STB?</b>	<b>&lt;int&gt;</b>
Parameter <int>	The status byte expressed as an integer between 0 and 255.
Description	Read the Status Byte from the instrument. Although the response is an integer, it represents 8 individual bits/flags. Only bit 2 is used in the multiplexer, and indicates an error is in the error queue. In general, it is easier to use SYST:ERR:COUNT? To check for errors, but this command is provided for compatibility with the SCPI standard.
Example	*STB?

<b>*TST?</b>	<b>&lt;bool&gt;</b>
Description	On receipt of this command, the device resets and executes an internal self-test. The response will be 1 if an error is detected and 0 if all tests pass.
Example	*TST?

<b>*WAI</b>	No Response
Description	Wait for the current operation to complete. This command is required for SCPI compliance, but all there are no commands which take time to execute, so the instrument will never wait.
Example	*WAI

## SYSTem commands

These commands are used to obtain information about the error queue. If the multiplexer detects an internal error, or it cannot parse a command from the PC, it will generate an error. Errors are stored in a queue, first in, first out, and as long as there is something in the queue the error LED on the front panel will be lit. Note that in some cases, one malformed command can generate several errors.

<b>SYSTem:ERRor[:NEXT]?</b>	<int>,<string>
Parameter <int>	A numerical error code. For a complete list of codes and their meanings, refer to the SCPI standard.
Parameter <string>	A short, human readable description of the error.
Description	Retrieves the error from the top off the error queue. As the queue is first-in first-out, this is the earliest error still in the queue. Once read, the error is removed from the queue. If there are no errors in the queue, it will return 0,No Error.
Example	SYST:ERR?

<b>SYSTem:ERRor:COUNT?</b>	<b>&lt;int&gt;</b>
Parameter <int>	The number of errors in the queue.
Description	Retrieves the number of errors in the error queue. The queue can store at most 16 errors, if that number is exceeded, the last error in the queue becomes a queue overflow error, and the other errors are discarded.
Example	<code>SYST:ERR:COUNT?</code>

## ROUTE commands

the route commands are used to set routes through the multiplexer. `Select` is exclusive, and will configure all relays so that only the specified route is set. More advanced configurations are available the via `H` and `L` commands. All `ROUTE` commands have corresponding query forms.

`ROUTE` commands are unavailable when the device is in monitoring mode, as in this mode the relays are controlled from the digital input port. The query forms remain available.

If a `ROUTE` command is issued when the device is in serial monitoring mode, an error will be recorded and no action will be taken.

<b>[ROUTe]:SELEct &lt;int&gt;</b>	No response
<b>[ROUTe]:SELEct?</b>	<int>
Parameter <int>	The channel to operate on, 0 to 4
Description	<p>The command exclusively sets a route in both high and low relay banks. Any other relays that were previously enabled are disabled.</p> <p>If called on channel 0, all relays are disabled</p> <p>The query form returns 0 if no relays are enabled, 1 to 4 if a route is exclusively set, -1 if more than one route is set, and -2 if the high and low relay banks are differently configured.</p>
Example	SELE 1

<b>[ROUTE]:&lt;bank&gt;# &lt;bool&gt;</b>	No response
<b>[ROUTE]:&lt;bank&gt;#?</b>	<bool>
Parameter <bool>	1 means the specified front panel BNC connector will be internally connected to the corresponding BNC connector marked COM. 0 means the specified front panel BNC connector will be grounded.
Parameter <bank>	H or L, corresponding the high and low relay banks.
Description	This command allows relays to be individual set, while the query form allows their state to be checked. Unlike <i>SELEct</i> , this command is not exclusive, so has no effect on other relays. The channel number in this case must be between 1 and 4, using 0 will cause an error and no action will be taken
Example	H1 1

## MODE commands

The MODE command is used to put the device in and out of serial monitoring mode. If the USB is connected, the device will always start in USB control mode and `MODE:EXT` can be used to hand over control to the digital input port.

<b>MODE:EXT &lt;bool&gt;</b>	No response
<b>MODE:EXT?</b>	<bool>
Parameter <bool>	1 means the device will be controlled from the digital input port. 0 means that the device will be controlled from the USB connection
Description	This command puts the device in serial monitoring mode. In this mode, the USB connection can be used to monitor the state of the relays but not control them. They are controlled instead by the digital input port.
Example	<code>MODE:EXT 1</code>

<b>MODE:PWRSrc?</b>	<bool>
Parameter <bool>	1 means the device is using power from the digital input port to control the relays. 0 means power is being derived from USB
Description	This query allows the user to check which power source is being used to operate the relays. It cannot be set over the USB serial bus, so there is no command form. Power from the digital input port is always used for the relays if it is present. The microcontroller always runs on power derived from USB.
Example	<code>MODE:PWRS?</code>



## Example Code Snippet

The following commands will enable channel 1, then disable it while enabling channel 2, then return to the initial state (all channels disabled)

```
SELECT 1
```

```
SELECT 2
```

```
SELECT 0
```

And here is an example of how you might achieve that in Python (requires PySerial to be installed):

```
import serial
import time

with serial.Serial('COM1') as mp240:

    mp240.write(b'SELECT 1\n')

    time.sleep(1)

    # take a measurement here

    mp240.write(b'SELECT 2\n')

    time.sleep(1)

    # take a measurement here

    mp240.write(b'SELECT 0\n')
```

The comments (#) should be replaced with code that takes a measurement from the capacitance bridge or other multiplexed device. The `time.sleep()` commands allow time for the multiplexer to operate and the capacitance bridge to adjust to the new reading, ensuring you do not receive stale data from the previous channel. These sleep commands may need to be adjusted or

removed according to the behaviour of your particular capacitance bridge.

## Caring for your MP240 Multiplexer

### Installing a Firmware Upgrade

Razorbill Instruments may add additional functionality in the future through firmware updates. This may involve adding support for additional commands and/or bug fixes. Razorbill Instruments may periodically contact you with updates that will be installed through the control PC, or you can check the Razorbill Instruments website.

### Cleaning

The multiplexer may be cleaned with a cloth dampened with warm soapy water or mild solvents like isopropanol. Avoid using abrasive cleaners, or using large quantities of liquid which could enter the multiplexer and cause damage.

## Firmware licencing information

The firmware uses two open-source components, `scpi-parser` and `LUFA`. The software licences and warranty disclaimers for these projects are reproduced below. Note that the authors of the open-source projects do not give any warranty on the code, but this does not impact the warranty provided by Razorbill Instruments, which covers the complete multiplexer, including firmware.

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## SCPI-PARSER

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