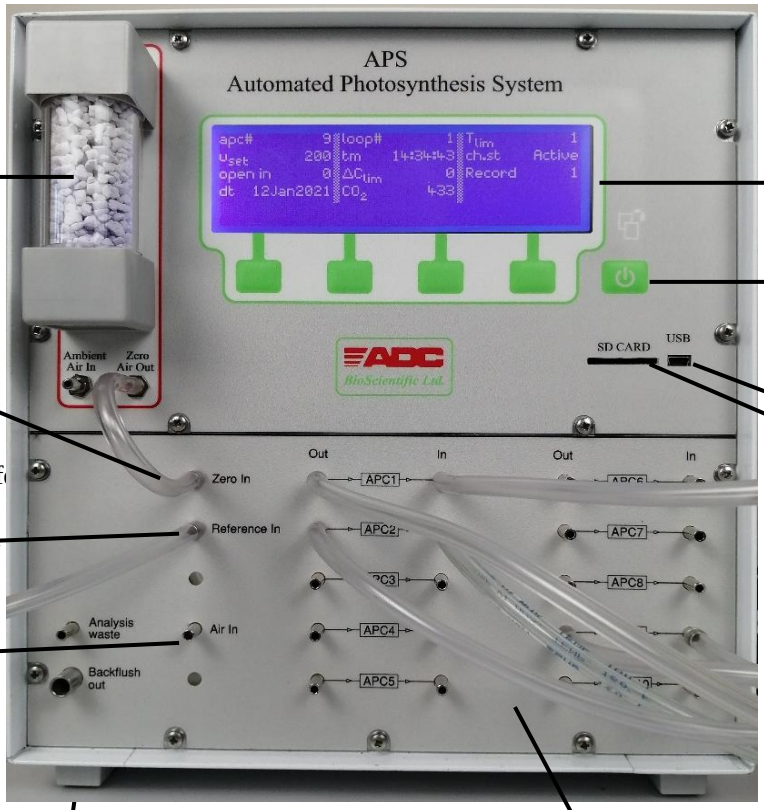
BioScientific Ltd.



Analysing the carbon cycle

APS Series, Multi-Chamber Automatic Photosynthesis Analyser and Controller



Soda Lime Column

Zero In connects to Zero Air Out (soda lime to remove CO_2)

Connect buff volume to Reference In

Leave Air In exposed (ambient air)

Backlit LED Display

5 Softkeys

USB Port

SD Card

Flip Down Feet

Gas Multiplexer supplying gas to and sampling gas from as many as 10 Chambers.

Technical Manual
ADC BioScientific Ltd.

Copied from APS man issue10

L.MAN-APS
Manual issue 1 13/9/22 Software issue 1 onwards

Contents

2 DESCRIPTION OF SYSTEM

The APS: A compact and portable multi-channel automated photosynthesis system with integral gas multiplexer. It consists of an analyser/controller and separate automated chambers connected with pipes and a cable.

Analyser: Comprises a CO_2 analysis cell and a two mass flow meters. The analyser has a sampling pump and air supply pump for each connected chamber. The cell is kept hot by thermostatic control to prevent condensation of water vapour and for measurement stability.

The front panel: Comprises a soda lime column, a backlit LCD display and 5 keys, a SD card connector and a USB socket.

Channels (one channel per chamber): The multiplexing valves and pumps are mechanically fitted at the factory in groups of 5, so that the analyser is offered in a 5 or 10 channel option.

Pumps: Each channel has its own pump for analysis and air supply, the latter being powered all the time to maintain constant flow.

Flow: While a channel is selected for analysis, its flow is measured with the flowmeter, and the corresponding pump drive for that channel is adjusted so the achieved flow equals the set flow. The achieved flow is maintained (if requested) remembered and displayed even when that channel is not selected for analysis.

Usual setup:

.

Input/Output Features:

- SD card to allow a data or control sequence to be saved and loaded.
- Configurable serial port.
- USB port for connection to a PC when the analyser looks like a storage device.
- Two voltage free relays which can be used to indicate when data is valid, or when the gas channel is changing, or for alarms.
- One analogue output (voltage or current) which can be related, by the user, to any of the measured or calculated parameters.
- Seven 12 bit analogue inputs.

3 SWITCHING ON AND OFF (SEE ALSO QUICK START GUIDE)

Connect the nominal 12V supply, provided, then press the **page**  **button** (far right) for at least 2 seconds. The following style of message will be shown:
APS Software PRD-1063 Ver 1.0
©1999-2014 ADC BioScientific Ltd
EN11 0NT www.adc.co.uk
Instrument Serial Number 33650 SW V1.03

The serial number and software version number should be quoted in any correspondence to us.
Immediately after switch on, the analyser will cycle all the inlet solenoid valves, also it will be warming up and unable to display CO_2 or H_2O readings. During this time, a status bar message 'Instrument is warming up' will be displayed.
If the left hand button is momentarily pressed immediately when the introductory message is displayed after turn-on, the warm-up timer will be bypassed. If this is the case, a popup message will inform the user accordingly, and there will be a message on the rolling message bar and the inlet valves will not be cycled. Alternatively, pressing the second button from the left during the time the introductory message is displayed, will disable gas corrections and the warmup timer. A message will be displayed to this effect also.

The APS can be switched off by pressing the **page button** continuously until the power off page is reached (alternatively, pressing the page button several times leads you back to the power off page).

4 ELECTRICAL CONNECTIONS

The front panel has a USB socket which allows an external PC to access the SD card for data download, and ports for connection of

The rear panel (shown in fig1) has:
●An external DC power socket, fuse protected with a car type fuse
●One M3 stud for electrically grounding the chassis. This is necessary for safety if either of the relay outputs are connected to mains power.
●RS232 serial connector for connection to a PC
●12 way pluggable connector strip for connecting:
Two single pole changeover relays
Up to 7 12 bit analogue input channels
2 relay outputs.
An analogue out of 0-5V or 4-20 mA
External DC supply or battery.
Note that the screws of the connector strip make electrical contact only when they are tight.

●A 7 way RS485 connector for the connection of the external leaf chambers. The connector also supplies DC power.

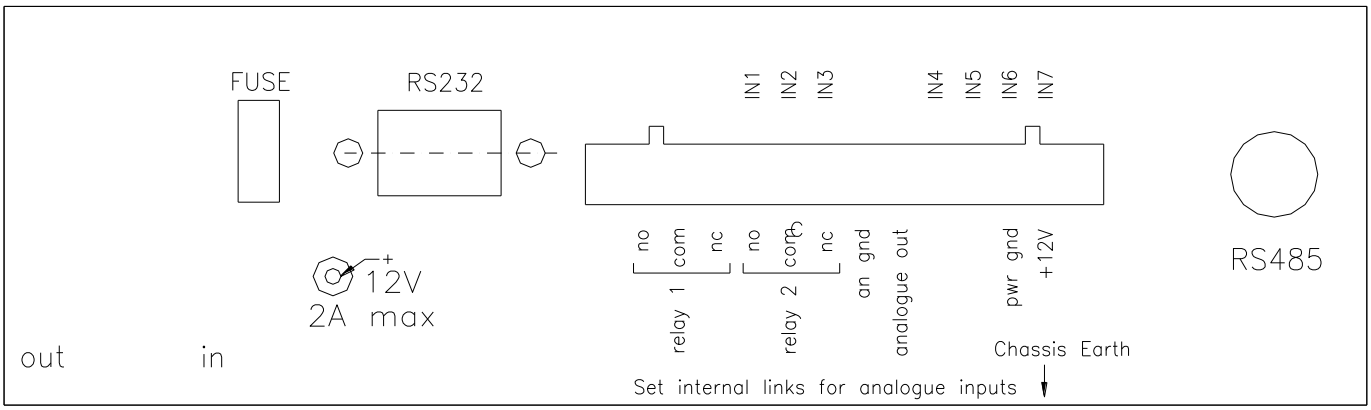


Fig. 1 Rear Panel Connections

5 GAS CONNECTIONS AND FILTRATION

The analyser has Luer tapered gas input connections on the front panel. The Luer taper has the advantage of easy fitting of flexible tubing and the possibility of fitting a range of readily obtained moulded plastic fittings.

It is better to try to minimise restrictions in the sample piping. This is because restrictions will force the pumps to work harder, reducing their life and consuming power, and because restrictions can increase the possibility of water dropout at the high pressure points when the air stream is near to dew point.

The instrument is supplied with push-on PVC caps on all the gas connections to protect against dirt during transit and storage. These must all be removed before it is turned on.

Filters
Hydrophobic filters of 50mm effective diameter (M.630-976) are supplied for all gas channels, to protect against water droplets entering the APS analyser.

Inlets. The inlets are coded with a white disc and are to be connected to the outlet of the chambers coded with a white band. If there is any risk of water condensing in the sample tubing and entering the APS analyser, please fit one filter (M.630-976) to every channel inlet. The filters have 1µ pore size; a smaller pore size will cause unnecessary restriction and may result in the pumps being unable to supply the requested flow. They also are large in area to allow good air flow. The filters require a short length of 4.8 bore adaptor tubing (eg our part number 706-100 or similar) at either side, to allow connection to the standard tubing between a channel and a chamber.
To fit filters to all the connections, it is necessary to fit the filters hanging below/away from the APS front panel, because the spacing of the gas entries is less than the diameter of a filter.

Waste Outlets. There are two waste outlets on the bottom left of the front panel, for the outlet of the analysis cell, and for the outlet of backflush. Restrictions in the backflush out line will cause the inlet flow on any channel to drop when it is switched to backflush, so if a pipe is fitted to this port it should be large bore and as short as possible.

Soda Lime Column Connections. There are two plug-in gas connections on the top left of the front panel for the soda lime column. The OUT connector for the soda lime should normally be linked with a short pipe to the zero in so that the instrument can establish the CO_2 zero. We

advise lengthening the tubing from the soda lime column to zero input so that it loops downwards to reduce the possibility that condensed water droplets enter the analyser.
When the instrument is not being used for an extended period of time, for example a week or more, the soda lime life will be extended by moving the link pipe so it connects the IN and OUT together, thereby sealing the soda lime loop.

6 GAS HANDLING SYSTEM

The gas handling unit can handle has up to 5 or 10 chambers depending on whether the -5 or -10 option has been purchased.
The solenoid valves are of a low power latching type, which maintain their state without power.

6.1 Flow

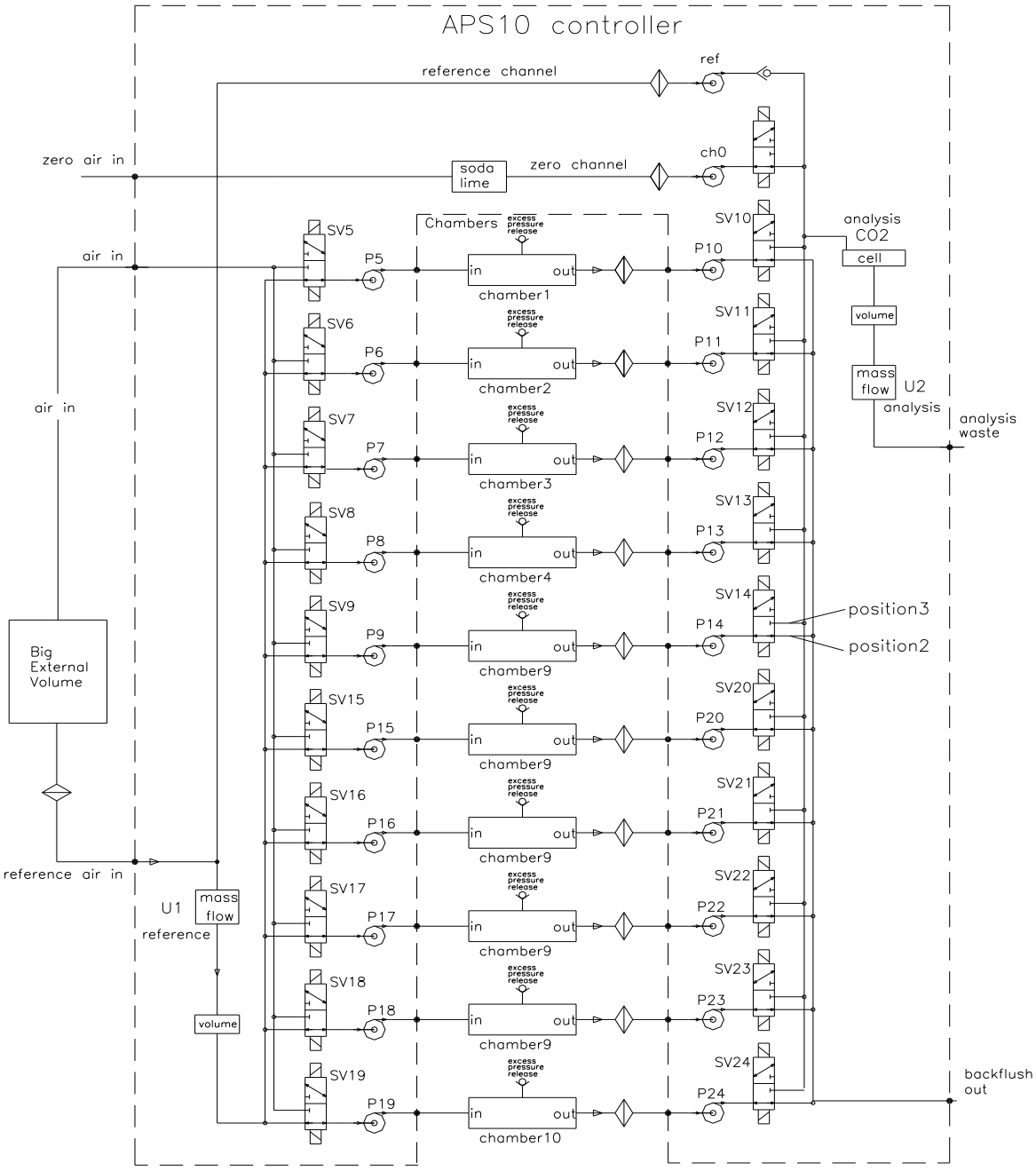
Each connected chamber is allocated its own diaphragm pump for fresh air, which can be set to be running all the time or immediately before and during the measurement. Continuous flow ensures that air for analysis does not need to be flushed through the pipes before it is valid.

When a chamber is selected for analysis its fresh air and analysis gas flows are measured and its pump drives are adjusted to achieve the set flow for that channel. When the channel is no longer selected the achieved flow is remembered and displayed in a table, and the drive to achieve that flow for the fresh air pump is maintained constant if constant flow has been requested by the user. Flow is set and displayed in µmol per second.

6.2 Timing ('on time')

In Auto mode, the analysis cell is connected in turn to the inlets. The **'on time'** for each channel can be set at a minimum of 2 seconds and a maximum of 999 minutes.

Note that these two settings interact: If the 'on time' is adjusted to less than the current 'data valid' time, then the 'data valid' will be reduced to match it and a pop up message to that effect will appear. Similarly, if the 'data valid' time is adjusted to be greater than the current 'on time', the 'on time' will be increased. A message will appear, informing the user.



7 GAS ANALYSIS SYSTEM

The gas circuit shown is for the 10 channel APS10 system. The 5 channel APS5 system is similar, with provision for 5 chambers only.

The APS10 has a CO_2 analysis cell to determine CO_2 concentration. A column of soda lime on the front panel is used to provide air stripped of carbon dioxide as a zero reference for the analysis cell. Gas connections to the column are made by the operator using lengths of PVC tubing (M.706-050), between the connection ports. This allows for a large column of soda lime to be connected externally for long term uninterrupted operation. Typically the output of the soda lime column is linked to the filter connected to the zero input.

Stripped air is supplied to the analysis cell by the zero channel solenoid valve. When the measurement of the stripped air is complete, the measurement value air is stored as the zero reference for the other CO_2 measurements. To ensure that the zero reference is good, the zero

channel flow and the zero channel 'on time' must both be high enough to purge the analysis cell of CO2 completely. E.g. at a flow of 250 µmol/sec, the 'on time' should be at least 90 seconds. The user can check the validity of the zero reference by watching the Can value drop to zero when the zero channel is selected.

If the instrument is in manual mode and set to channel zero, the software will allow the 'on time' that has been set for the zero channel, then it will set the zero reference. This zero process must be done before any CO_2 measurements are meaningful.

The analyser has an atmospheric pressure sensor to calculate a pressure compensation factor for the gas measurement. The gas temperature is taken as that of the gas analysis cell, which is temperature-controlled by the microprocessor.

8 TUBESET TEMPERATURE CONTROL

The microprocessor controls the cell temperature which is fixed at 45°C to eliminate the possibility of water condensation in the analysis cell and to improve analyser stability. Other temperatures can be set at the factory. Control is to within ±2ºC.

9 DATA LOGGING

Data points (records) can be logged at set time intervals, minimum every 2 seconds, by either:

- Manually pressing a record button
- On 'data valid'
- Relay 1 operation
- A high level on the CTS line of the RS232 connector.

The log due to 'data valid' occurs 1 second before the end of 'data valid'. If, for example, 'data valid is 2 seconds, the log will occur 1 second after the start.

To obtain a high level on the CTS line (which is pin 8 on the 9 pin D type connector), connect it to 12V via a 1800 ohm resistor or connect it directly to the adjacent pin 7 which is internally connected to 12V via a 1800 ohm resistor.

Data can be logged either to the SD card or the serial port.

The data logged to the SD card appears in a spreadsheet with a main title of the instrument type and serial number. Each column has a title for the parameters with the appropriate units.

Recd#, Record number
dt, Date
tm, Time
apc# Current plant chamber (1,2,3…)
reach, parameter to determine when the measurement is stable enough to be valid (Tlim…)
Qleaf, PAR value at the leaf (reduced by the transmission factor)
eref, e reference
Δe Difference between the e readings
VPD, vapour pressure deficit
Cref, CO_2 reference

Difference between the CO2 readings ΔCO_2
tch, Chamber air temperature
tleaf, leaf temperature
U, fresh air flow (For the current chamber)
Uset, set air flow
p, atmospheric pressure
ci, intercellular CO2
E, transpiration
gs, stomatal conductance
A, photosynthetic rate
rb, boundary layer resistance
Vbatt, power supply voltage
Tlmtd, method by which leaf temperature is calculated
rb, boundary layer resistance
trans, Window transmission factor
Area, leaf area
Analogue input 1
Analogue input 2
Analogue input 3
Analogue input 4
Analogue input 5
Analogue input 6
Analogue input 7
Relays status (bit 0 =relay1, bit 1=relay2)
Comment (single character)

Data output through the Serial RS232 Port is output in the same order but without titles.

10 RELAY OUTPUTS

Relay 1	**Relay 2**
6A 250V AC rating	0.7A 110 V AC rating
Default activated when jaws closed	Default activated on 'jaws closed'
The factory default is that Relay 1 energises for 1 second, 1 second before a channel change. This is called the data valid pulse	Relay 2 closes for 1 second, 1 second before the zero channel changes.
User options: Increase the on time of relay 1 to make it closed for up to as long the channel is selected. Configure as an alarm for any of the analogue inputs or CO_2 or H_2O level. Configure to activate on : gas level analogue input level 'data valid'	**User options:** Configure as an alarm for any of the analogue inputs or CO_2 or H_2O level. Configure to activate on : gas level analogue input level 'data valid'
SAFETY If either relay is connected to a mains power system, you must provide external fuse protection in the relay circuit and also earth the analyser. Earth using the M3/4 earth stud on rear panel. The attached earth cable must have a sufficient current rating to blow the fuse in the event of a fault.	

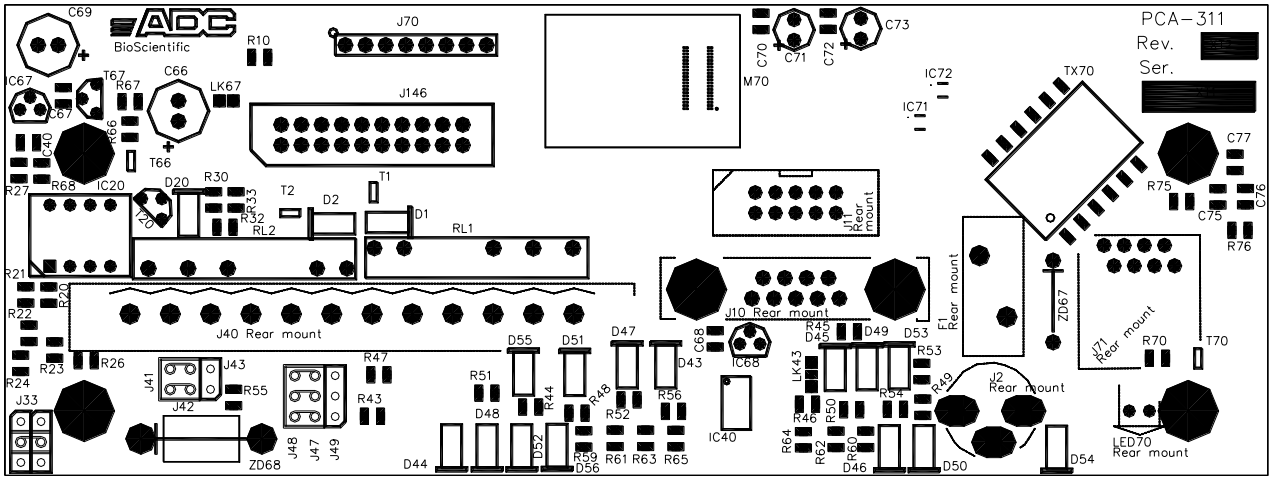
11 ANALOGUE OUTPUT

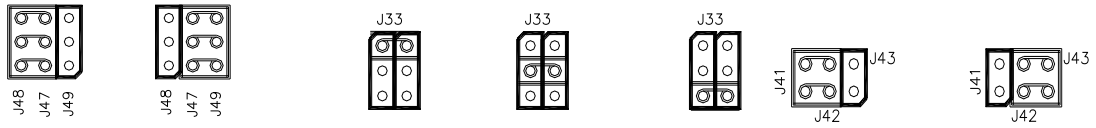
There is one analogue output **'an.out'** of either 0-5V or 4-20 mA which is hardware selectable with an internal link. The factory default is 0-5V representing the channel number that is currently selected: 0V=ch0, 200mV=ch1, 400mV=ch2, 600mV=ch3, 800mV=ch4, 1V=ch5 etc, or 4mA=ch0, 20mA=ch24 etc.
The software allows adjustment of the FSD (Full Scale Deflection) to a scale factor as low as 0.904. The span and zero has a software adjustable range of +/-5% for span and zero. So full digital scale of analogue out represents 5.25 +0.25, and the software allows subtraction of up to 0.5 for zero and a scale factor as low as 0.904.
The analogue output has a default range out of 0-5V which can be changed to 0-2.5V by asking your dealer to remove surface mount resistor R20 (10k) on the rear interface board or to 0-10V by changing R21 from10k to 30k. The 4-20 mA option is internally link selectable on the same circuit board, and there is a further option of 5V DC for powering any external sensors which might be connected to the analogue inputs

12 ANALOGUE INPUT

There are up to 7, 12 bit analogue inputs **'an.in'** nominally 5V maximum, allowing the APS to act as a data logger e.g. collecting the data from an attached analyser. The connections for the inputs are shared on the back panel with other electrical connections e.g. relays; the analyser is shipped with a factory default of two channels available. If additional inputs are required they

can be specified at the time of ordering, or user-selected by removing the rear panel and moving links. The impedance of each input is 4100 ohms and there is a 5% attenuation due to the overvoltage protection network. These inputs are displayed as 0 – 5.00V.





Relay2 in 1,2,3 5VDC out 5V an. out 4-20mA out pwr,gnd an 6,7

Fig. 3 PCA-311 layout. To show position of user-selectable links

13 INTERNAL LINKS

There are not enough connections on the rear panel connector plug for all the analogue in, out and relay lines simultaneously, so the required connections are link selectable internally. See [Fig. 3] above.
The 2 pin link on J33 determines what is connected to the Analogue Output screw terminal of the connector shown in Fig. 1. In the top position it selects constant 5VDC, which can be used for a constant power for energising external sensors. In the middle position, it selects 0 to 5V. In the lower position, it selects 4-20mA. The factory default position is the middle position.

If the 6 way block on J48, J47 and J49 is fitted between J48 and J47 then the screw terminals are selected for connection to Relay 2. If the block is fitted between J47 and J49 then these screw terminals are used for IN1, IN2, and IN3. The factory default position is the right hand position, i.e. IN1, IN2, and IN3.

If the 4 way jumper block on J41, 42, 43 is fitted between J41 and J42 then12VDC power and power ground are selected. If this block is fitted between J42 and J43 the IN6 and IN7 is selected. The factory default position is the left hand position i.e. power and ground.

14 SERIAL PORT

The serial port on the rear panel allows for logging to a remote destination.
The baud rate defaults to 115200 and can also be programmed by the user.

15 POWER SUPPLY

The analyser is supplied with a universal voltage mains power to 3A 13.8V DC converter with regulated output. Note that it will run from an unregulated supply but the performance will be reduced, particularly pump flow stability. A 12V regulated supply is also OK.
The processor monitors the supply voltage and displays a condition bar.
Power is most conveniently connected with a coaxial type power plug which has a body diameter of 5.5mm and central hole of 2.5mm. Power may also be applied via the 12 way removable screw terminal connector on the back panel provided the internal links LK40 and 41 on circuit board PCA-311 have been correctly set. The factory default is that they are set to enable external power on the connector.

16 REAL TIME CLOCK

The APS has a real time clock to time and date stamp records. The clock will continue to keep good time from an internal rechargeable battery for up to 4.5 weeks. The internal battery needs to have external power connected for about 27 hours to fully recharge, but the instrument does not need to be switched on.

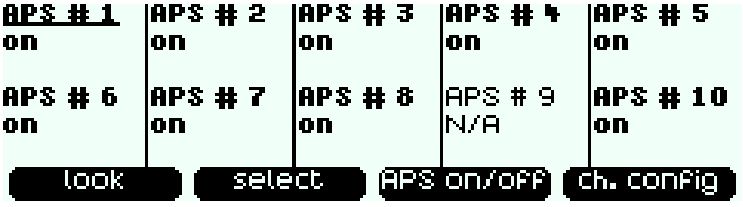
17 MENU STRUCTURE

The display has a proportionally spaced font, and 4 ‘soft’ keys below the display which are configured according to the menu page that is displayed.
Caution: If the left button (number 1) and number 4 are pressed at the same time, the instrument will perform a software reset.

Button  or ‘page’ button cycles through 4 main menu screens, or returns from a sub-menu page, see below:

17.1 Main Menu 1

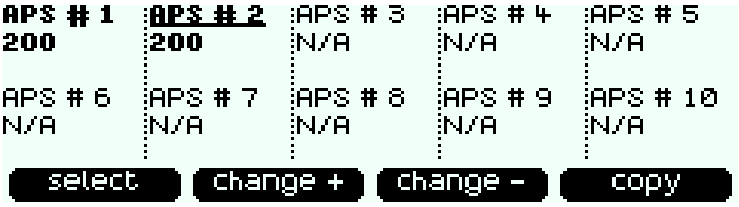
Page 1 displays every connected chamber (APC) up to a maximum of 10. This page is the first to be shown at power-up.



● Press the button below “Look”, to trigger the APS to look for connected chambers. Chambers will display as “On” or “Off”. A disconnected APC will display as “N/A” (example APS #9 above).
● Press the button below “Select” to highlight each APC in sequence. Once highlighted, an APC can be switched on or off.
● Press the button below “APS on/off” to choose whether the selected APC is on or off during an experiment. A ‘look’ will reset an ‘off’ chamber to ‘on’.
● ‘page’ takes you to main menu page 2.

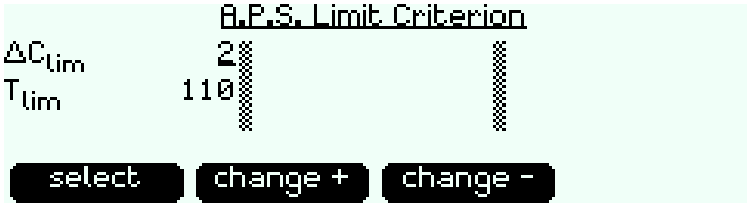
● Press “ch. config” to enter the first sub-menu: which will either allow the fresh air flow, area of leaf in the chamber, maximum duration of the measurement, CO2 stability value for terminating the measurement, number of measurement loops around all the connected chambers, to be set.

Here is the menu for setting the flow. Press quickly to decrease flow by 1µmol s^{-1}. Hold down to decrease by 10µmol s^{-1} steps
All chambers are shown, but only the active ones can have their flow set.

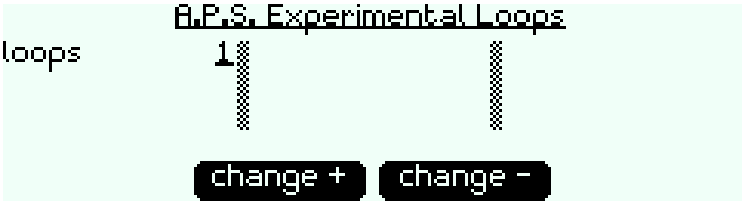


The copy facility is a quick way to set the next chamber to have the same flow as the current one.
The leaf area menu has the same format and is not shown. Press quickly to decrease flow by 1 cm^2. Hold down to decrease by 10 cm^2 steps. These steps are too big and are due to be changed to 0.01 and 1 respectively.

This is the ‘set lmt’ (set limit) menu which sets a value for both the CO2 stability and time (in seconds). The measurement on the current chamber will finish when either of these values has been reached. The ΔC lim value is calculated from the average of the modulus of the last 25 ΔCO_2 values.



This is the ‘set loops’ menu. Edit the number of cycles or “loops” that the APS performs, continuously, to measure all APCs selected as “ON”. Set this value to “0” to perform continuous loops. A value between 1 and 225 loops may otherwise be set.
Press quickly to increase loop by 1. Hold down to increase by 10 steps.



17.2 Main Menu 2

This is a list of the connected chambers, and whether they are on, off, or are disconnected.
‘page’ takes you to main menu page 3.
‘check sens’ is a non-operational function which is yet to be added.

‘check apc’ takes you to a page where you are here invited to start a set of

measurements to determine the Delta C stability values for all the selected chambers at their individual flows and limit times. This function is currently not properly working.

‘run’ will take you to this page where a measurement run has already started, but it can be paused or stopped. ‘pause’ is currently inoperative.
‘stop’ will cause the run to stop after the end of the current measurement, so will not be immediate.

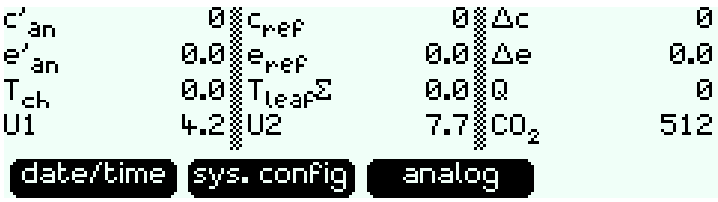
If, instead of ‘start’ you press the page key, you will go to the page where the chambers parameters can be set:

17.3 Main Menu 3

Previous APC and Next APC: Press to move from one APS to the next or the previous APC, to view every setting for each chamber in turn.
Pressing ‘page’ moves to main menu 4

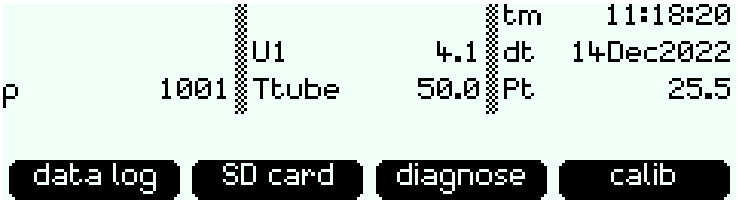
17.4 Main Menu 4

Shows measured and calculated parameters for the live APC

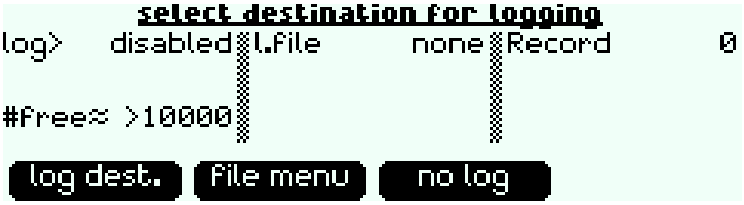


‘date/time ‘ will invoke this menu.Date and time have been set in the UK

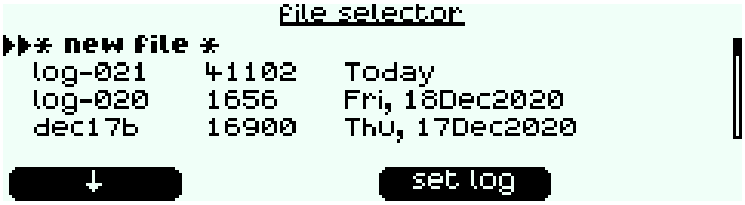
Data Log: Takes you to the page below.
SD Card: Displays SD card information and erase options. Note that , when an SD card* is installed, a red light will show next to the card slot (there may be a delay if the card has a large storage capacity). Information about the card will not be valid until the light has turned OFF
Diagnose: Displays engineering system information. See below.



This is the 'data log'menu.
Log dest.: Toggles between "File" (log file is saved to the SD Card), and Serial (serial port, accessed on the back panel) or Both (SD card and serial port). To disable logging completely press 'no log'
The maximum number of files that can be stored on the SD card is approx. 50. A warning message will display when that limit is exceeded.
This screen-shot shows that 0 log records have been sent and that no log file has been selected. It also shows that logging destination ('log>') has been set to be disabled



File Menu: Select from a pre-saved file, or create a new file and name it using 'set log' The log file name is automatically set to the next highest number, but retaining the alphabetic prefix "log". All the characters of the file name can be changed using the alphanumeric character set shown. The file name must be unique



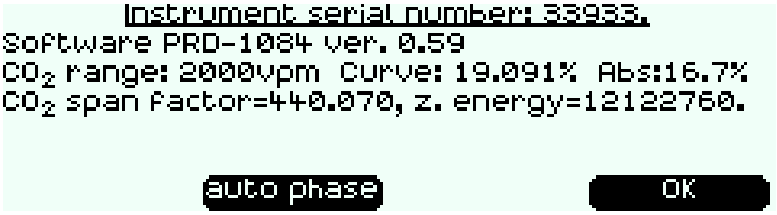
17.11 Diagnose Menu

Select 'diagnose' from the 'sys config' page gives the following menu which has live readings:

[ca] The A-D counts corresponding to the gas that is currently in the analysis cell.
[c]z The A-D counts corresponding to zero gas (through soda lime)
[cab]a The CO_2 absorption factor.
Vbatt. the voltage from the external power supply.
Tcomp
MSPver The software version of the slave processor.

page returns to the 'Config' Menu.

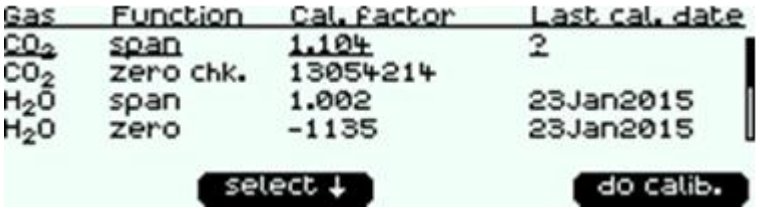
17.12 System Information Menu



The curvature number relates to the CO_2 linearisation curve.
OK and page both return to the previous 'diagnose' page

The **'auto phase'** is intended for engineering use if a new analysis cell detector has been fitted.

17.14 Calibration menu



The units to be calibrated are shown underlined; in this screen snap, CO2 span is underlined and so has been selected.
Use the arrow to scroll down to the options not shown on this screen: (flow span, flow zero, anop. span, and press. trim.)
The calibration date is shown as a '?' if the calibration has been lost, otherwise it shows the last calibration date.

An.OP trim is a +/- 5% scaling factor that is applied to the analogue output of 0-5V or 4-20mA. One of these (either V or mA) must be connected to the analogue output via an internal selector link (see section: "internal links").

Flow zero
Check flow zero before performing flow span (below).

Flow span
Connect the APS up to channel 1 only, by selecting channel 1 ('on') in manual mode. The instrument uses its internal pump to pass air through the external standard flowmeter. Flow zero should be checked and adjusted if necessary before a flow span is performed.

H_2O Zero
Perform an H_2O zero prior to an H_2O span. The procedures are performed similarly (below).

H_2O span
Connect the APS up to channel 1 only, by selecting channel 1 ('on') in manual mode. The instrument assumes that you are pumping the flow externally. If you do not have your own pump, then, before starting the calibration procedure, channel 1 should be set to a fairly high flow, around ¾ of the full scale, and channel 1 should also be permanently selected using the manual option. The instrument automatically uses a flow of 200 µmol/sec.

CO_2 span
To perform a CO_2 span, the APS must have already measured 'zero gas' in 'auto mode' or have just done a CO_2 zero*****. The span gas is then applied to channel 1 (through a 2 stage regulator and throttle, NOT directly from a cylinder[#]) using a 'Tee' connector with three ports. This prevents excess flow from pressurising the instrument.

#Span gas from a cylinder must NOT be connected directly because the pressure from a compressed gas cylinder will damage the instrument. Span gas must be supplied through a regulator (2 stage type preferred) and a throttle to reduce the flow to somewhere in the range 250 to 500 µmol m^2 s^1. The instrument automatically uses a flow of 200 µmol m^2 s^1, so there will be excess flow escaping from the Tee connection

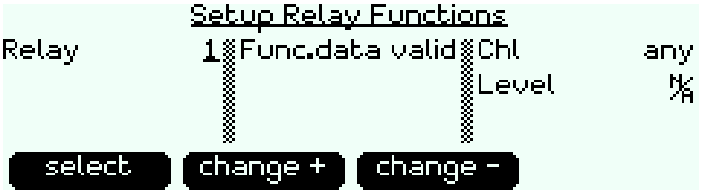
CO_2 zero

A CO_2 zero adjusts the gain of the detector amplifier so that the detector signal arriving at the analogue to digital converter (A-D) is centred in the A-D dynamic range. During a CO_2 zero procedure, the instrument automatically uses a flow of 200 and also sets the gas zero.

This will not normally be required for several years after purchase. Only performed after analysis cell parts have been replaced, or the instrument has dust deposition inside the cell.

A CO_2 zero is performed by removing the top rear panel and slowly rotating the RV19, until the pointer on the bar graph is centred. Please note: The ribbon cable that connects the top rear panel is not long enough to allow the panel to be lowered to the work bench. To prevent the cable being strained by the weight of the panel, *remove the top two nuts that fix the lower rear panel*, move the panel up and *temporarily fix the panel to the bottom two holes of the top panel.*

17.15 Relays Menu



Relay 1 changes to Relay 2 with change+ and change- and the associated parameters change accordingly.
Having selected the relay, you can then view or modify the settings, Settings are automatically saved when you switch relays or exit the screen.

Relay 1 or Relay 2 can be set to operate on the Functions of: data valid, CO_2 level (for any or all of the gas channels), H_2O level (for any or all of the gas channels), and analogue input level for any of the voltage input channels.

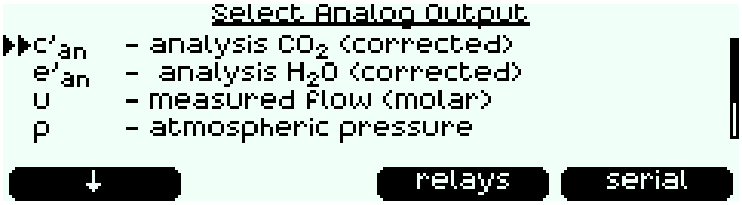
The relay is active at greater than or equal to the Level set in the units relevant for the Function. For example ppm for CO_2.

Chl (channel) selects the channel number (1 to 25 if function is set to CO_2 or H_2O or 0 to 7 if function is set to analogue in).

When the Function is set to CO_2 or H_2O the channel may be selected as ‘all’. The instrument checks the CO_2 level and sets the relay accordingly only during data valid. So the relay state will remain on its setting for the previous channel until data valid is true, and then may change state several times if the CO_2 level changes through the threshold level set by you.

The analogue voltage range for channels 1-7 is between 0.05 to 5V in 50mV steps.
The CO_2 range is between 0 and 2000ppm in 20ppm steps.
The H_2O range is in mBar.

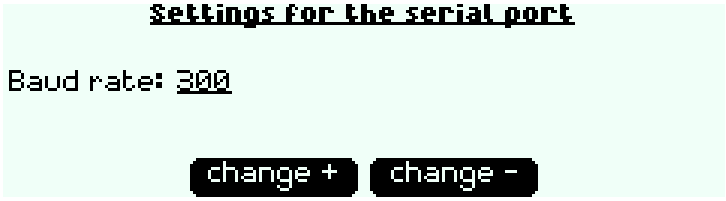
17.16 Output menu



Others in the list obtained with the down arrow are:
Ttube: Gas analysis cell temperature
[C]z: CO_2 analysis zero point, counts
IpChl: Input channel

page returns you to Menu 1 Screen, with the last highlighted choice selected.
serial switches you to the Serial Setup Menu:

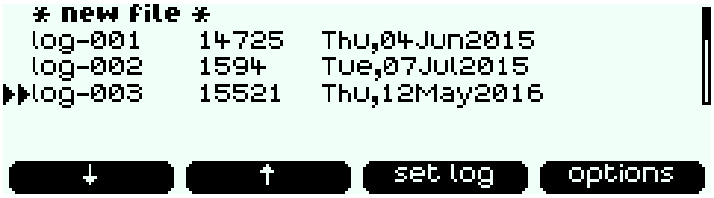
17.17 Serial Setup Menu



baud rate cycles between 300, 1200, 2400, 4800, 9600, 19200, 38400, 76800, 115200 and 230400. The factory default setting is 115200.
page returns you to the Output Menu.

17.18 Logging Menu

Note that logging is disabled when the APS is in its warm-up phase.
The maximum number of files that can be stored on the SD card is 50. A warning message will display when that limit is exceeded.
This screen-shot shows that 67 log records have been sent.
It also shows that logging destination ('log>') has been set to be both to a file on the SD card called log-013 and to the serial port. If logging had been disabled, 'disabled' would be shown as the logging destination.
Logging destination can also be set to a single destination; 'serial' or 'file'.



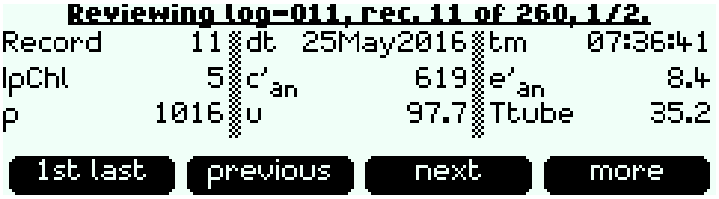
File menu brings up the adjacent menu:
Here the down arrow will scroll through all the file possibilities.
The solid part of the vertical bar graph, on the right of the screen, shows where the viewed page lies in the total list of files. Use the down arrow to access more log-files.

If "new file" is chosen as set log the adjacent menu appears:
Log file name is automatically set to the next highest number, but retaining the alphabetic prefix "log". All the characters of the file name can be

changed using the alphanumeric character set shown. The file name must be unique.

Press ‘options’ to rename, delete or review a file.

Each file record is displayed over two pages. Here is the first page of the eleventh record of a typical record file. Do not remove the SD card during a record review.



Data storage capacity and limits:

There is a limit on the number of files that the APS is able to access. This number is between 61 and 200 depending on how the card has been formatted. When this limit is reached, a popup message will appear:

Too many files to show!
Some files may not appear on this list – please
delete files to make room
OK

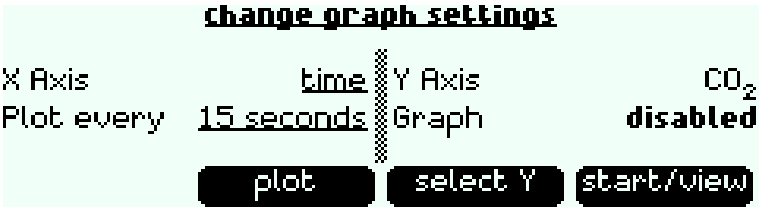
The limit on the number of record is much higher; around 40 million for an 8 GB SD card (10 million for a 2GB SD card).

17.20 Graphing

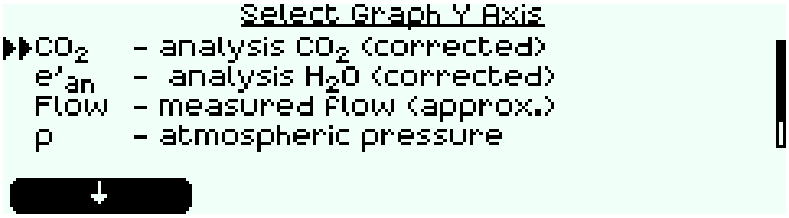
To edit and begin a graph, press ‘graph’ on Menu 1 Screen

Select the vertical (Y) axis of the graph with ‘setup’

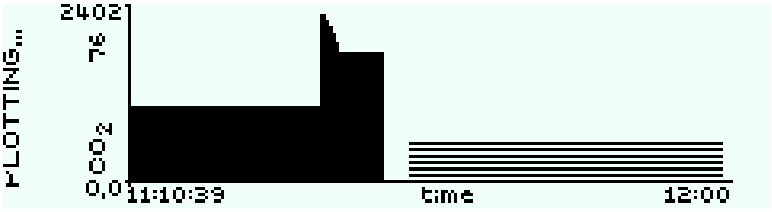
Press plot to change the timing of each data point.
Options: either once per data log, or every 15, 30, 60, or 300 seconds.
Note that if you wish the graph to be synchronised to the channel numbers them it is necessary to set the plot to every log record, and set the logging to record on data valid (see section 17.8). It is not sufficient to set, for example, plot every 15 seconds and ‘on times’ also to 15 seconds.



SelectY to select from 8 vertical (Y) axis parameters, as shown opposite: including **[C]z** (CO_2 analysis zero point, counts), found by using the arrow button.



start/view initiates the graph, which automatically scales in the Y direction, and scrolls in the X direction when it is full.
The lower and upper limits of the vertical axis are shown, in this example 0.0 and 2402.
The horizontal axis never shows zero on the left.



The most recently plotted value is shown sideways. In this example it is CO_2 with a value of 76ppm. The block of horizontal lines indicate a set of values which were outside of the plot range, in this case, < 0

There is a simple way to avoid your x axis data being compressed if a large transient Y value is about to appear:

Pause automatic X axis scaling:

1. Press any button whilst graph is running
2. A pause and copy button appear
3. Press pause to change 'PLOTTING' to '*PAUSED*'
4. There are now no further additions to the Y axis (X axis continues)
5. Press any button again
6. Press resume button to change back to 'PLOTTING' so the Y axis updates again.

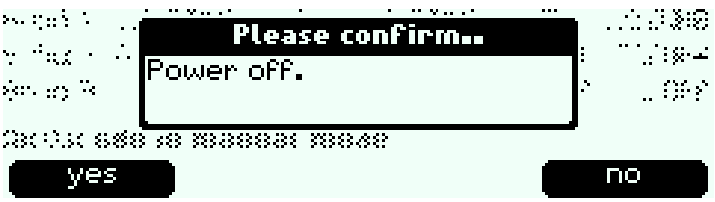
This feature is also useful if you wish to make changes to the pipework or experiment connected to the analyser, but do not wish to record any correspondingly large changes in data to the graph.

The lack of Y axis updates during PAUSE causes a gap to show on the graph for a time corresponding to the pause, so this feature is also useful as a way to add markers to the graph.

The copy button will place a bitmap image of the graph onto the SD card with a filename in the form GRAPH01.BMP. The file number will automatically be incremented: GRAPH01 etc.

17.21 Power off menu

'Yes' causes the instrument to power down
'No' returns you to Menu 2 Screen.



18. CHECKLIST FOR SETTING UP THE APS

1. Initial setup:

1. Unpack, check all contents and remove protective coverings. Install the cylinder of soda lime (white chemical) onto the front panel of the APS.
2. Position your Controller unit and Chambers so as to minimise the longest interconnect pipe length. Flip down the feet on the Controller for easier viewing of the display.
3. Use a 5 to 10cm length of the tubing supplied, to connect the zero channel to the soda lime column "OUT". Once you are using your APS, regularly check that the soda lime is a fresh white colour. Thoroughly purple soda lime will need to be replaced.
4. Cut lengths of tubing to the required length, to reach from the channel input connectors to the top of each soil sample column (leaving a little extra length will allow you to re-cut the ends of tubing in the future).
5. We advise connecting the disk shaped hydrophobic filters supplied (630-976) to the inlets on the APS front panel. Filters are recommended to reduce the risk of dirt and moisture entering the APS unit. Use adaptor sleeves of cut tubing (706-100) to fit.
6. If you are using Ambient Air as the Reference Gas, connect channel 1 to an empty column (labelled column 1 or reference). This will monitor the reference and give you a control.
   Alternatively, if you are connecting to Soda Lime as a Zero Air Input, fill the first column with soda lime and connect this to channel 1.
7. Connect your first sample column to channel 2, the second to channel 3 and so on, in sequence.

4. Configure the APS to your required settings:

Using the menu buttons, enter 'configure' and then 'setup' on the APS.

4a. Set the flow rate to each channel.

- Select Menu 3 screen.

- Select 'Set Flow' to view this screen:

'Z' is for zero channel (connected to soda lime column).
1,2,3,4 are the sequential channel numbers.
'on' tells you which channel is currently being measured.

Default flow rate is **200 μmol/sec**. To change values;

- Select a channel using the arrow keys (down, across).
- Set flow for each with 'set flow'.
- Change flow value with '+' and '-' keys. Press quickly to increase the value by 1 unit. Hold the key to increase by 10.

- Use ‘Copy flow’ to quickly copy this value into several channels.
- Use ‘on/off’ to switch a channel’s pump on or off (e.g. to connect an external pump or gas source). All channels will still be sequenced, even when ‘off’. This means that the analyser will remain on each channel for the specified ‘on time’.
- Use  to go back one page and select another channel using the arrow keys.

6. Save settings as a ‘Setup’ file (not yet available)

- Enter the **Config**. Menu
- Press **load/save**
- Select **new file**, and create a name (you are given 8 characters).
- Select **Settings ‘YES’** and **Preferences ‘YES’** to save all your preferred settings.
  You can use ‘load’ on the Config. Menu to easily and quickly reload this and additional setup files. For example, if you and/or additional users need to change between different measuring protocols or samples.

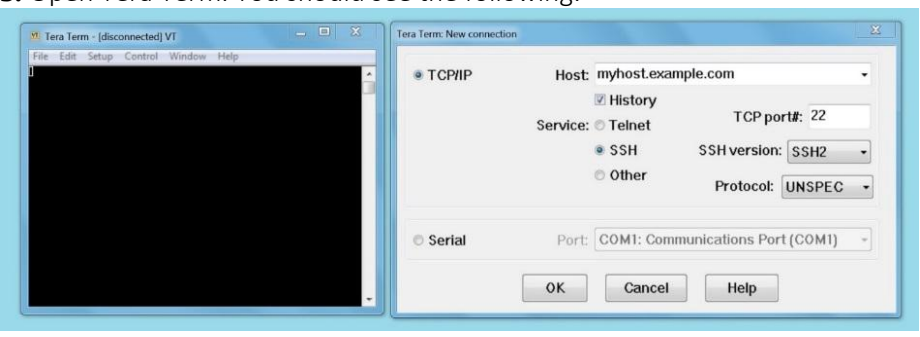
Connecting APS to a computer device for direct data retrieval

You may choose to connect an RS232 cable, or a RS232 to mini USB cable between the APS and PC or laptop. The RS232 plug must be “female” at the APS end. If using an RS232 to RS232 cable, the PC end also needs to be “female”.

1. Install a free, terminal emulating software for example “Tera Term”. Please ensure compatibility with your computer operating system and scan any new software for viruses prior to installation.

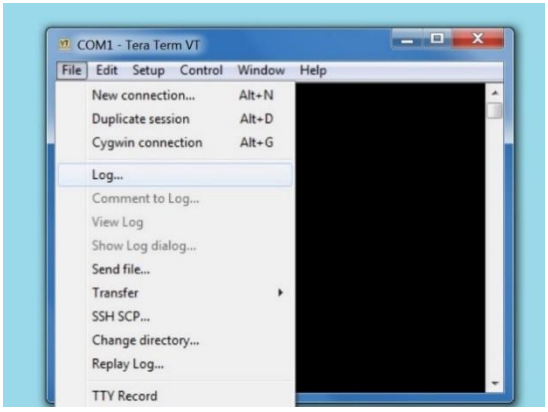
2. Connect an RS232 cable or RS232 to mini USB cable to the RS232 port on the back panel of the APS. If a RS232 to USB cable is used, it may need a driver software to be installed. Try this procedure first, without a driver.

3. Open Tera Term. You should see the following:

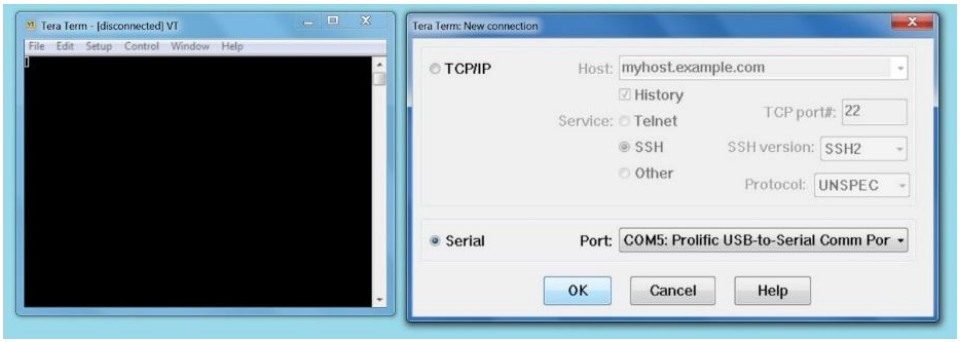


4. Select the serial option and select correct port*.
   The correct port can be identified by noting the list of available ports on Tera Term, then closing Tera Term. Disconnect the RS232 cable then reopen Tera Term.
   Again look at the list of ports and see which option is missing. That missing port is the correct one to select. Close Tera Term, reconnect the cable, reopen Tera Term and select the correct port.

5. In Tera Term, click ‘FILE’ then select ‘LOG’ from the drop down list.



6. The log options box will now pop up. Select a destination for the log file and enter a file name ending with “.csv”. Select the options as shown:



7. Click ‘SAVE’. The log file may now be sent to the PC/laptop.
8. On your APS, enter the ‘LOGGING’ menu and press ‘FILE MENU’
9. In the next menu, use the up and down arrows to select the file you wish to transmit. Next, press the ‘OPTIONS’ button.
10. In the next screen, press ‘SEND’.
11. In the next screen, press ‘ASCII’ at the top left:
12. The file will now transmit to the PC/laptop. When this is completed, the message “Transfer complete O.K.” will appear.
13. Close the Tera Term terminal on the PC/laptop and select ‘SAVE’ if a save option appears on the screen.
14. Finally, open the CSV file from the location chosen earlier on. It should open with Microsoft Excel™ or a similar program.

19 PARAMETER INFORMATION

Symbol	Description	Log #	An. o/p?	Menu	Units	Type	Range
Record	Current record number	1		2 and logging			
Dt	Date (text)	2		3			
Tm	Time (text)	3		1			
IpChl	Input channel	4		1 and 3			0 - 24
C'an	CO_2 analysis (corrected for dilution)	5	y	1	ppm	M,Co	0-2000
e'an	H2Oanalysis, dilution corrected	6	y	1	mBar	Ca,Co	0-100
p	atmospheric pressure	7	y	configure	mBar	M	600-1100
u	Achieved flow	8	y	3	µmol s^{-1}	M	68-341
Ttube	Analysis cell temperature	9	y		°C	M	-5 to +50
Relays	Relay in operation	10	y	2			1, 2
Power	Voltage	11			V	M	10.5-14.3
A1-7	Analogue input 1-7	12-18			V	M	0-5.0
CO2rdg	Analysis CO2 format: Raw or Average	19					
Power	Bargraph showing supply voltage			1		M	10.5-14.3
Log:	Name of log file			3 and configure		G	
[C]z	Raw A-D counts for CO_2		y	diagnose		M	0-166777216
Mem.	Free space on memory card			card	M bytes	C	

The "Type" column indicates the method of derivation, according to the following code:

- Ca = Calculated (generally by a formula given in the appendices)
- Co = Corrected (by terms defined in the appendices)
- F = Factors (established by experiment or other means)
- G = Given (i.e. entered by the user)
- K = Constants (physical or scientific)
- M = Measured raw values by transducers

20 ROUTINE MAINTENANCE

20.1 CO_2 Stripper

The performance of the Controller is dependent on the satisfactory condition of the soda lime stripper, which is in the column on the front panel. The life expectancy of the soda lime depends on; ambient conditions, the 'zero' flowrate and 'on time'. To minimise the usage of soda lime, the instrument switches off the zero pump when the zero channel is not being used as reference gas.

The Controller is supplied with an indicating type of soda lime, which will work until 90% has changed colour. After this point, the soda lime becomes 'exhausted' and will not function. To

maintain the performance, always replenish the Soda Lime when the colour first changes from white to violet.
NOTE: The soda lime colour change is temporarily reversible until it is fully depleted.

Re-conversion back to soda lime is not practicable. Some water content is necessary to assist the chemical reaction, which is to convert CO_2 to calcium carbonate + H_2O. This increases the moisture content of dry air.
NOTE: If the analysis CO_2 reading '**Can**' falls below 100 ppm, a warning message appears and prompts the user to check the soda lime, which may be exhausted.

20.2 Gas Filters

The gas connections on the front may become blocked with dirt if the instrument is placed with this surface downwards. If the bottom outlets on the left are blocked, it may be possible to carefully poke at the blockage with the instrument running, so that the debris is expelled. We recommend to fit loops of pipe to the entries when they are not connected.

When the instrument is not in use, e.g. being transported, we recommend keeping and using the PVC caps supplied with the APS, to place over all gas entries.

If dust or pollen is drawn in from the air supply, this eventually may cause a malfunction of the mass flow sensors and/or the optical bench. The APS filters are designed to prevent this, but will gradually restrict the airflow in the process. If difficulty is experienced in obtaining the maximum flow of 230 µmol m^{-2} $sec^{-1.}$ (i.e. the indicated flow 'u' is very much less than 230 µmol sec^{-1} and pump is "racing"), this is a sign that filters should be changed.

Note: In dusty atmospheres, with continuous operation, and no other external filtering, filters can become blocked in less than a week. If in doubt, compare filter colour with one in the spares kit.

20.3 Suggested Maintenance Schedule

O-rings: check for wear or damage each time the soda lime column is changed or removed. Take care not to damage the large o-rings on the column when re assembling. Keep these O-rings free from chemical granules and lightly greased with silicone grease (supplied in the spares kit).

Soda lime: Replace when the colour changing indication shows that approximately 80% of the chemical has been used.

External filters: Regularly inspect external filters to ensure they are not clogged. The hydrophobic filters supplied will prevent water droplets entering the Controller when used on the front panel gas inlet connections. The filters should

always be connected in the same direction of air flow which is indicated on the moulding of the filters, to avoid dust and water droplets entering the console (which may clog the internal filter and damage the analyser). A badly clogged filter may damage its associated pump (as the pump works harder to overcome impedance).
If there is a lot of water condensate causing the filters to regularly become blocked, it may be wort considering the use of equilibrator tubes which have the ability of removing water from the air stream by equilibrating the humidity on the inside of the tube with that on the outside

Recommended Recalibration Schedule:
CO_2: at least once every year
H_2O: every two years
Whole instrument: 4 years, to be carried out by ADC BioScientific Ltd.
The last calibration dates are to be found on the calibration screen.

20.4 Tools

For dismantling the APS and replacing parts: No specialist tools needed

To replace electronic components:
Small, thermostatically controlled soldering iron+
Anti-static wrist strap (especially when working on the digital board).

For testing leaks:
A sphygmomanometer without the cuff
OR a water manometer connected with pipe and a tee to a 100ml disposable syringe
A small paintbrush – to apply soapy water where a leak might be suspected

For cleaning:
Cotton wool buds or alcohol are good for cleaning the cell (do NOT use methylated spirits)
Small paintbrush for gentle, general cleaning

Replacing screws:
All screws are metric except the hexagonal pillars on the 'D' type connectors.

Fitting/removing pipes:
All pipes are push-on although some have been fitted using 'Hellerman'™ oil, which allows pipes to push on easily, but sticks them in place when dry. If a pipe will not pull off easily, do not continue to tug as the pipe tends to become thinner and grip even tighter. Instead, use **a pair of thin nosed pliers** with one jaw either side of the connector to push on the end of the pipe. Do NOT use a sharp blade or knife, especially for removing any barbed plastic fitting around pipes. These may be damaged by a sharp blade, causing leaks.

20.5 Accessing the Inside of the Main Instrument

With the controller switched off, unscrew the M3 screws securing the front panel. The panel can then be lifted off and to one side.

If you are planning to dismantle or remove parts, take photographs of each step for reference.
Care should be taken to protect the display membrane as it can be easily damaged.
The digital board (PCA-307) is attached to the display panel and, unless you are taking static precautions, you should avoid touching the electronics. Do NOT pull on the electrical cables.

20.6 Air Flow (Mass Flowmeter)

The mass flow meter is in a feedback loop with the pumps, and the microprocessor will drive them faster or slower until the set flow is achieved. If a pump has stopped or is going as fast as possible, the mass flow meter may be faulty. If there is a leak inside the console, in the piping between a flow meter and its pump, the pump will run faster than normal, but insufficient flow will emerge from the flow meter. See leak testing, below:

The two air mass flow meters are very stable. If its calibration changes, the cause is almost certainly contamination inside it. If this happens, a replacement of the flow meter is recommended. It might be possible to blow out the contamination if it is dust, but if it has been carried into the flowmeter by liquid, the flowmeter will almost certainly need replacement. The flowmeters (part number M.368-270 FS4001-1000-CV-A), are on the PCA309 board plugged in to a socket and mechanically attached with two screws. Support the flow meter with one hand when removing or refitting the pipes with the other. After replacement, it is recommended that a flow zero calibration is done using the menu system, and this is simple. If you have access to a good standard mass flowmeter, the flow span may also be done.

20.7 Leak Testing

Leaks may be easily tested for using a water filled manometer and an inflation bulb connected with a 'Tee'. Connect the manometer to the gas circuit to be tested, and apply about 10cm water gauge of pressure to the manometer and inlet. Wait a few seconds for the manometer reading to settle then note the reading. Wait a further 10 seconds then, if you cannot detect a fall in the reading the system is sufficiently leak tight.

20.10 Cleaning Dust from the Analysis Cell

During the CO_2 measurement cycle;
1. The analysis cell is supplied with air which has been stripped of CO_2 by the soda lime.
2. The detector signal is then measured and stored.
3. The analysis cell is then filled with air for CO_2 analysis
4. Again, the detector signal is measured and stored.
5. The CO_2 concentration in the air that has been supplied to the analysis cell is calculated from the ratio of the two detector signals.

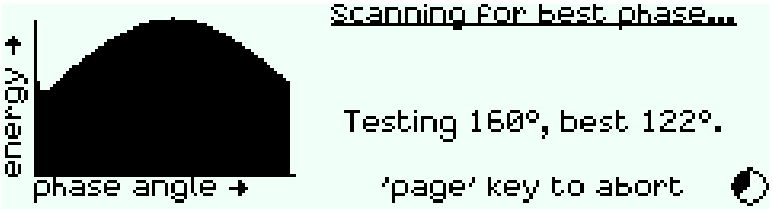
The analysis cell may collect dust after prolonged operation. Small amounts of dust will not affect the CO_2 reading.

It is usually only after several years of continuous use that dust will reduce the detector signal and cause an error message to be displayed when the software can no longer correct for the reduced signal. When this happens, it is necessary to remove and clean the analysis cell.

Removing and cleaning the analysis cell:

1. Unclip the flat white plastic ties around the cell insulation but leave them in place, held under the lower insulation block.
2. Lift off the top insulation, remove the 2 screws holding the heater resistors.
3. Disconnect the 3 way connector for the detector and the 2 way connector for the source, and the 2 way connector for the cell temperature sensor
4. Remove the 4 nuts and washers holding the cell in place
5. Lift out the cell, noting that 4 metal spacers remain in the lower insulation block.
6. Disconnect the two pipes by the method described in the tools section.
7. The screws each end of the cell can now be removed.
8. The cell is best cleaned with a good quality, nonabrasive cotton wool moistened with iso-propyl alcohol or ethyl alcohol. The cotton wool can be wrapped around the end of a thin wooden stick or pulled through the cell with strong cotton.
9. Wipe the widows* with cotton wool moistened with alcohol if they look dirty.

*__Take care with the windows__ which are made from calcium fluoride, as they are brittle and can be easily scratched.



Immediately remove any water which may enter the cell:
Water not removed will cause corrosion leading to permanent discoloured patches inside the analysis cell. If these are large in area, they will remove so much infra-red energy from the beam that it may be impossible to set zero. In that case the cell will need to be replaced or returned to ADC for re-plating. Even small areas of damage may affect the linearity of the cell response and hence the accuracy of measurement.

20.11 Source and Phase

If the source looks blackened, it should be replaced for best signal and lifetime. The new source may respond at a different speed to the old one, so the phase difference between the source drive waveform and the detector waveform may change. To optimise the detected signal, the phase relationship should be checked using the auto phase menu, when you will be presented with a graph similar to that shown here. For this, the instrument automatically chooses a flow of 200µmol/sec.

20.12 Display Contrast Setting

The normal contrast setting for the display changes little with variations in ambient temperature. Manual re-adjustment to suit your preference is via the ‘contrast’ potentiometer RV127 in the upper right corner of circuit board PCA-307. This can be accessed by removing the front panel of the controller as previously described, and looking at the panel from above.

20.13 Software and Serial Number

The software part number and version and the instrument serial number for the APS are shown on the display when it is first switched on. The serial number is also shown on a label which is

attached to the rear panel. These details should be quoted in any correspondence. The ADC part number for the software is PRD1084. If the instrument is in a dismantled state for servicing, the software part number and version can also be found on a label attached to the digital board (PCA-307).

20.14 Software Upgrades

The software on the controller can be upgraded from a file which ADC has sent you. A typical filename might be APS-00.IMG for software version 2.00.
To install new software:
1. Ensure that there is no printer connected to the serial port.
2. Copy the file to an SD card if it is not already on one.
3. Turn on the controller.
4. Plug in the SD card.
5. A message will appear saying ‘New firmware is available on this SD card. Do you want to update the firmware?’ Accept this option.
6. A confirmatory message 'Firmware update cannot be undone! Are you SURE you wish to continue?' will appear. Again accept this.

The software will then be updated and the instrument will restart.
The operation is quick but must not be interrupted. Please ensure that the power is reliably connected and that the card is fully inserted, to avoid corruption of the software.

21 TECHNICAL SPECIFICATION

Pump flow maximum at least 340 µmol/sec

Flowmeter: scale 680 µmol/sec

Flow measurement accuracy +/- (1.5% of reading + 0.5% of scale)

Heated analysis cell at factory default of 40 deg C

DC Voltage in: Minimum 11.5V Maximum 17.5

DC Current in: 2A maximum. Protected with replaceable fuse

Analogue input channel resolution: 12 bit, accuracy +/- 1.5%

Overall case size including feet, handle & entries cm: 17 depth x 25.5 width x 28.5 height

CO_2: Span 2000 ppm as standard
Resolution: 1ppm

H_2O: Resolution: 0.1mBar

Atmospheric Pressure range: 600-1100 mbar. Accuracy -4/+2 mbar

IP rating 42

Weight with 10 channels and filled stripper column 8.55kg TO BE VERIFIED

Width 260mm x Depth 191mm x Height 284mm (including stripper column but without packaging or accessories)

Specifications subject to change without notice

22 SPARE PARTS

All parts listed are available to order from ADC BioScientific Ltd. direct or through your local ADC product support centre.

M.706-145	Tube PVC 6mm OD x 4mm ID
M.630-976	Hydrophobic filter 1µ 50mm diameter filter for Controller inlets
M.706-100	Tube 8mm OD, 5mm ID 20cm length supplied to be cut and fitted to filter M.630-976
M.809-151	Silicone Grease 100g tube
M.994-283	USB cable
M.022-804	FUSE car mini blade 2A
M.197-715	Secure Digital card 4GB SanDisk
M.614-660	FEMALE LUER 5/32" Barbed.
M.650-652	O RING 6.07ID X 1.78mm Spouts of the chemical column
M.651-551	O RING 28.30ID X 1.78mm The ends of the chemical column on the controller
M.614-697	Coupling, Luer 3.0mm Male MTLL230-6005
M.614-802	air entry, 2 off for constructing a buffer volume.
M.LCM-069	Stripper (soda lime) column assembly.
M.407-930	PVC cap 3.9 bore.
M.299-449	Power Supply

<u>Accessories and Additional Spares Available to order</u>

M.EGA-033	External battery kit. 7Ah Lead Acid Battery and 2m cable. Emergency power supply in case of laboratory power cut or accidental removal of power cable during data logging. APS has no internal backup battery.