MICRO-PAM
MONI-DA

Manual

2.174/04.2025
8. Edition: April 9, 2025
MicroPam09.docx

Heinz Walz GmbH · Eichenring 6 · 91090 Effeltrich · Germany
✆ +49 9133 7765-0 · 🖷 +49 9133 5395
✉ info@walz.com · 🕸 www.walz.com

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1 Safety Instructions

1.1 General Safety Instructions

- Read and follow safety and operating instructions prior to operation of the device. Pay attention to all safety warnings.
- The devices, MICRO HEAD/3B measuring head and data acquisition system MONI-DA, are designed for outdoor use. Still, avoid as much as possible exposure of devices to dust, sand and dirt.
- Always, care must be taken to keep sockets clean. During field operation, the sockets must be closed either by screw caps or by cable plugs. Plugging and unplugging of lines, as well as handling the MicroSD card require dry and clean conditions.
- Keep all ports of MONI-DA and MICRO HEAD/3B clean and dry.
- Run all cables so that stepping on or stumbling over them is excluded.
- Ensure that neither liquids nor foreign bodies get inside the device.
- Do not put these devices near sources of heat.
- Connect the device only to the power source indicated in operating instructions or on the device. If the device is not in use, remove the mains plug from the socket.

- Do not open housing of MICRO-HEAD/3B, interface boxes or MONI-DA. There are no serviceable parts inside. The device may only be repaired by the manufacturer.

1.2 Special Safety Instructions

- The MICRO-PAM system is a highly sensitive measuring system which should be only used for research purposes, as specified in this manual. Follow the instructions of this manual in order to avoid potential harm to the user and damage to the instrument.
- The measuring heads MICRO HEAD/3B can emit very strong light! In order to avoid harm to your eyes, never look directly into the light port or fiber optics of the measuring heads.

2 MICRO-PAM: General Description

The MICRO-PAM is a system integrating up to 16 measuring heads for long-term monitoring of plant photosynthesis. The simultaneous monitoring of several sites is now a well-proven concept to obtain statistically significant information about the performance of photosynthesis under natural conditions.

The individual measuring head of the MICRO-PAM system is a compact and energy-efficient PAM fluorometer equipped with a high-performance LED. A 3 mm diameter light guide establishes the optical connection between LED and sample. The measuring head is equipped with a leaf temperature and a humidity sensor.

MICRO-PAM measuring heads are available as BLUE Version with blue LED (MICRO-HEAD/3B) or as AMBER Version with amber LED (MICRO-HEAD/3A).

In the simplest form, a MICRO-PAM system consists of a computer to which up to four measuring heads can be connected. In the absence of line power, the data acquisition system MONI-DA replaces the computer. Special adapter boxes (MICRO-HUB) allow connecting up to 16 measuring heads to a single MONI-DA.

MONI-DA-based systems can be upgraded with a WiFi or a satellite modem. In this configuration, the MONI-DA sends data to the user's computer via a Walz server specially set up for this task.

3 MICRO-PAM Systems

3.1 MICRO-PAM Measuring Heads

A MICRO-PAM measuring head consists of a plastic box with special protection against ultraviolet radiation. The box contains all optoelectronic components required for measuring PAM fluorescence and saturation pulse analysis. Light guide and cable port are placed at opposite sides of the box (Fig. 1).

The box is supported by an aluminum plate. Two holes in the aluminum plate extent to the plastic box. Each hole is closed by a special ventilation membrane. One hole gives access to the internal humidity sensor.

Mounted 1 cm beneath is a bipartite aluminum structure forming a leaf clip in front of the light guide. The leaf clip is held together by magnets. Open leaf clip only by applying pressure on the lever at the bottom of the MICRO-HEAD/3B (see Fig. 1, p. 6). The other end of the aluminum structure has a recess to connect the measuring head to a stand. One gooseneck-type stand is provided for each measuring head.

The sample plane of the leaf clip and the fiber optics form an angle of 60°. The PAR sensor (Mini Quantum Sensor LS-C) is attached to the edge of the clip around 5 mm above the sample level. For distant light sources like the sun, the PAR measured by the sensor applies to the sample level.

Centrally positioned underneath the leaf clip is a thermocouple which is mounted on a steal spring. The thermocouple should touch the lower surface of the sample. When needed, adjust thermocouple to the sample by manually bending the spring.

The indicator LED of the measuring head (cf. Fig. 1, p. 6) shines green when fluorescence values range between 300 and 700. The LED turns red when the fluorescence value is outside of this range. With the sample in the dark or exposed to dim light, the fiber should be positioned so that signal LED shines green, that is, the signal is in the target range of 300 to 700.

The signal should not fall much below the lower limit of the target range to avoid low signal quality; the signal should not exceed the upper limit to avoid signal saturation during a saturating pulse. The principle considerations for estimating the upper target range are outlined in Table 1 which considers that the highest PAM value is 4000 and assumes an F_V/F_M value of 0.84.

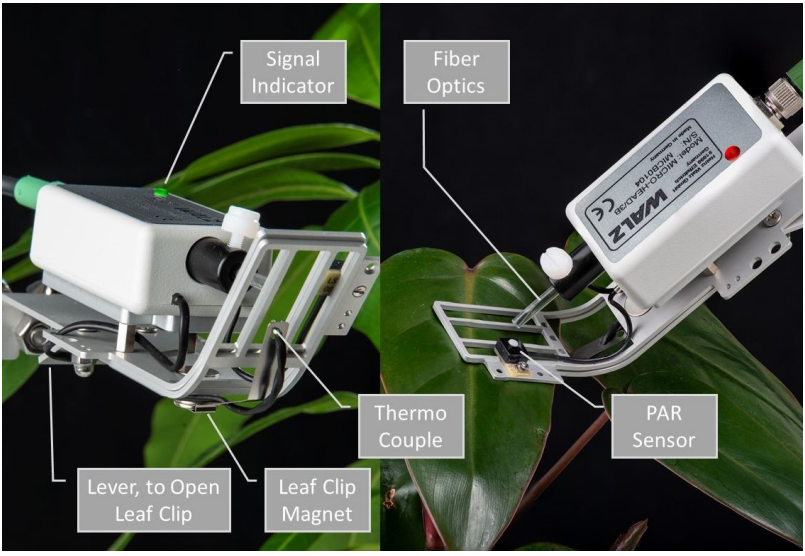


Fig. 1: MICRO-PAM Measuring Head

3.2 BLUE & AMBER Version

MICRO-PAM systems can be configured with measuring heads MICRO-HEAD/3B or MICRO-HEAD/3A. The measuring head MICRO-HEAD/3B probes photosynthesis with blue light which has a peak intensity at 460 nm and full width at half maximum of 27 nm; the measuring head MICRO-HEAD/3A possesses an amber LED with emission peaking at 598 nm and a full width at half maximum of 22 nm (Fig. 2A).

BLUE and AMBER Versions are further distinguished by the spectral window for fluorescence detection. The BLUE version detects fluorescence at wavelengths > 600 nm, whereas the AMBER version detects fluorescence at wavelengths > 700 nm (Fig. 2B).

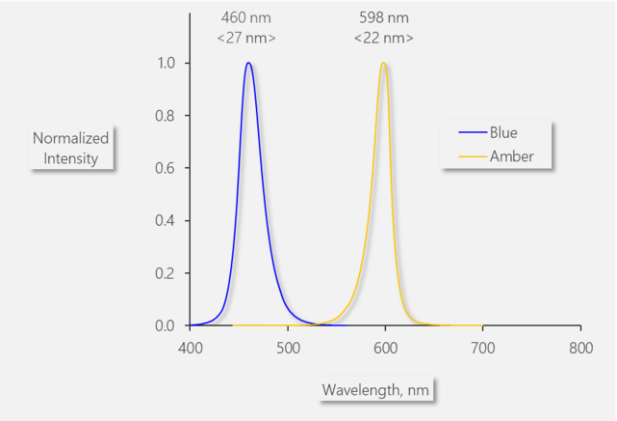
MICRO-PAM and MONI-PAM systems employing blue light have successively proven itself in terrestrial and aquatic research.

However, amber light is better absorbed by cyanobacteria than blue light. Correspondingly, the quality of the PAM signal excited by amber light is superior to that excited by blue light. For this reason, MICRO-PAM systems configured with measuring heads MICRO-HEAD/3A are particularly suited to probe cyanobacterial mats and lichens, or crusts containing cyanobacteria.

Table 1: F_0 Fluorescence

$\left(\frac{F_V}{F_M}\right)_{Max} = \frac{(F_M)_{Max} - (F_0)_{Max}}{(F_M)_{Max}}$	$(F_M)_{Max}$, maximum possible F_M value = maximum value of MICRO-PAM = 4000.
$with\ (F_V/F_M)_{Max} = 0.84$	$(F_0)_{MAX}$, unknown maximum F_0 value (the F_M associated with this F_0, or with smaller F_0, is not saturating).
$(F_0)_{Max} = 640$	$(F_V/F_M)_{Max}$, assumed maximum possible PS II photochemical yield.

A



B

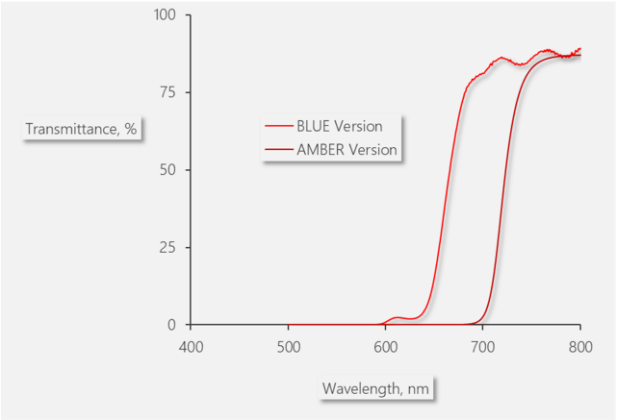


Fig. 2: BLUE & AMBER Version

A: Typical LED emission spectra normalized to their maxima. The blue curve corresponds to the spectrum of the blue LED of the measuring head MICRO-HEAD/3B, the amber curve represents the emission of the amber LED of the measuring head MICRO-HEAD/3A. Peak wavelengths and full width at half maximum (bracketed) in nm are displayed.

B: Transmittance spectra of detection filters in the measuring head MICRO-HEAD/3B (BLUE Version, red line) and measuring head MICRO-HEAD/3A (AMBER Version, dark red line).

3.3 General Advice

Take care that the PAR sensor is not shaded by a neighboring leaf.

Position thermocouple carefully to avoid penetration of delicate samples.

Under rainy conditions, a water droplet can persist on the tip of the fiber optics. The droplet changes the optical properties of the measuring heads and may cause a signal drop. As a signal reduction will affect all fluorescence levels, the Y(II) remains unaffected, in most cases.

Do not carry out saturation pulse analysis at high frequency as this might stress the sample, particularly during the night. Intervals between 30 and 60 min are sufficient for most studies. On request, we provide a batch file which reduces the SAT pulse frequency automatically during dark periods.

When data of individual heads or of the entire system are repeatedly missing, check if water has got in any of the plug connections.

4 ONLINE Configuration

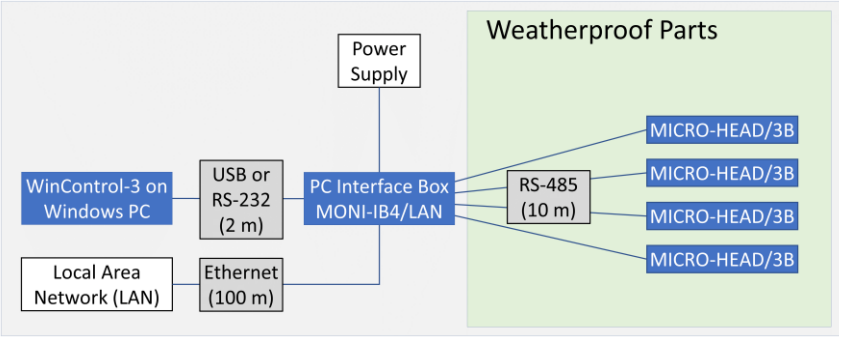


Fig. 3: MICRO-PAM ONLINE Configuration

The scheme shows the standard package MICRO-3B-SET4. PC, Ethernet cable or RS-232 cable must be ordered separately. Weatherproof parts are drawn on light-green background.

In the ONLINE configuration (Fig. 3) of the MICRO-PAM, the software WinControl-3, running on a Windows computer, controls data acquisition. The interface box MONI-IB4/LAN (Fig. 4) has four RS 485 ports to connect up to four measuring heads. Opposite to the RS 485 ports, the box is equipped with three communication ports: USB, RS 232, and Ethernet. Located at the same front is a connector for the charger.

The ONLINE configuration requires line current for the measuring heads and for the computer. In addition to USB communication, the interface box MONI-IB4/LAN permits connecting to a local area network (LAN). RS-232 is available for special applications.

Fig. 4: MONI-IB4/LAN

5 STAND-ALONE Configuration

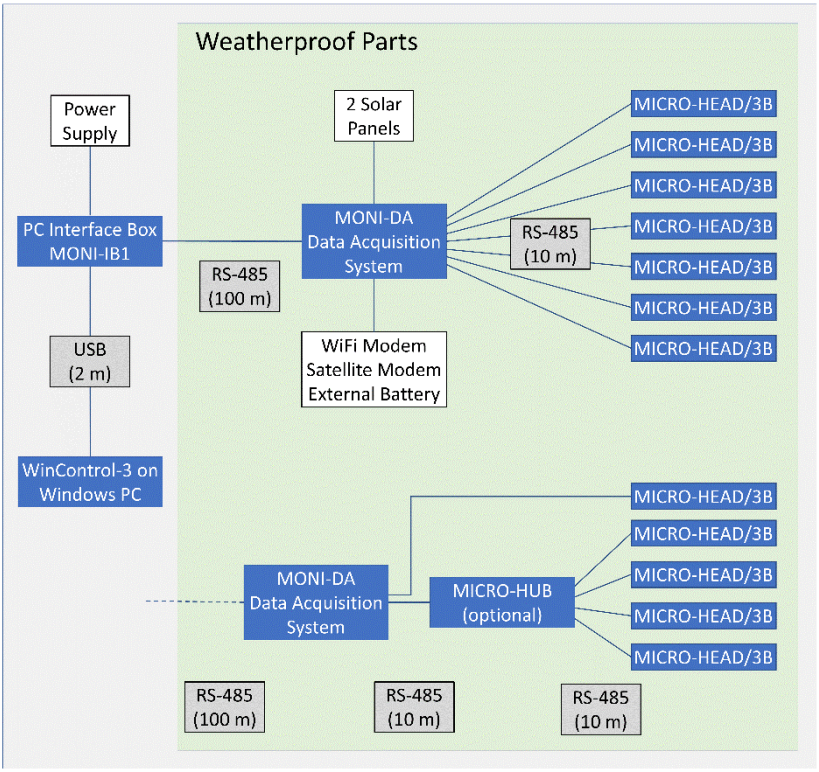


Fig. 5: MICRO-PAM STAND-ALONE Configuration

Upper part, setup with seven measuring heads connected to the MONI-DA. Standard packages include three or four measuring heads (MICRO-3B-SET3-DA and MICRO-3B-SET4-DA, respectively). Lower part, up to 16 measuring heads can be connected to the MONI-DA when the optional MICRO-HUB is used. Weatherproof parts are drawn on light-green background.

The STAND-ALONE configuration of the MICRO-PAM is designed for field research without line current. Control of measuring heads and data acquisition is performed by the weatherproof MONI-DA

data acquisition system. The battery of the MONI-DA is charged by solar panels.

For long nights at polar sites, an external high-capacity battery can support the internal battery of the MONI-DA.

The MONI-DA has seven so-called MONI-BUS ports to which MICRO-PAM measuring heads can be connected. The MONI-HUB permits connecting four measuring heads to a single MONI-BUS port. Thus, the number of measuring heads can exceed the number of seven. Because of memory-limitations, the maximum number of measuring heads is 16.

5.1 MONI-DA Data Acquisition System

The same data acquisition system is employed by MONI-PAM and MICRO-PAM systems. Therefore, this section presents a broad view on Walz data acquisitions systems including the data acquisition system MONI-DA for terrestrial use, and the data acquisition system MONI-DA/S for aquatic use. The MONI-DA is compatible with measuring heads MICRO-PAM and MONI-PAM/485, the MONI-DA/S is compatible only with measuring heads MONI-HEAD/S.

5.1.1 General Description

The data acquisition systems have been developed for unattended, long-term and multi-site monitoring of photosynthesis. The data acquisition systems MONI-DA (MICRO-PAM and MONI-HEAD/485) and MONI-DA/S (only MONI-HEAD/S) permit battery-powered measurements of photosynthesis of terrestrial and aquatic plants, respectively. Common properties of the two data acquisition systems are:

- Waterproof and robust housing.
- Low power consumption.
- Dual data storage on ring buffer chip and memory card.

Major differences between MONI-DA and MONI-DA/S are

- To avoid water leaks, the MONI-DA/S lacks the memory card port of the MONI-DA and, hence, the card cannot be removed. For the same reason, signal LEDs are omitted on the rear face of the MONI-DA/S. For data download see Section 5.4.2.
- All sockets of the MONI-DA are M12 5-pole but in the MONI-DA/S, waterproof 6-pole sockets are employed.

5.1.2 Battery and Power Consumption

Following the rapid development in battery technique, we have equipped data acquisition systems with different batteries (Table 2).

Table 2: MONI-DA Batteries

Serial number	Date	Battery type	Voltage, Charge
CFMH#### (MONI-DA) CFMK#### (MONI-DA/S)	Before June 2011	Sealed lead-acid (contact Walz to have the lead-acid battery exchanged for a lithium iron-phosphate battery)	12.0 V, 7.0 Ah (Low battery warning at 11.5 V, auto shut down at 7.5 V)
CFMP#### (MONI-DA) CFMS#### (MONI-DA/S)	After June 2011	Lithium manganese oxide	7.2 V, 4.8 Ah (Low battery warning at 6.8 V, auto shut down at 6.5 V)
	After November 2012	Lithium iron-phosphate	12.0 V, 7.5 Ah (Low battery warning at 11.5 V, auto shut down at 11.0 V)

Charging MONI-DA batteries requires that one of the PC interface boxes (MONI-IB1, MONI-IB4/LAN, MONI-IB1/S or MONI-IB4/LANS) is connected to the mains and to the data acquisition system.

A full charge cycle of the lithium iron-phosphate battery requires approximately 6 hours. The readout of the MONI-DA indicates the battery charging state (see Section III).

Power consumption of a MONI-DA system is 5 mW in the standby mode. In the measuring mode, this value is increased depending on the number of the emitter-detector heads connected and on measuring conditions. To give an example, with 7 emitter-detector heads delivering saturation flashes every 15 minutes the system runs on lithium iron-phosphate batteries for more than 4 weeks.

In most cases, power supply by the two solar panels delivered together with MONI-DA systems (MONI-SET-3-DA or MONI-SET-4-DA) is sufficient for long-term operation of the system without line power.

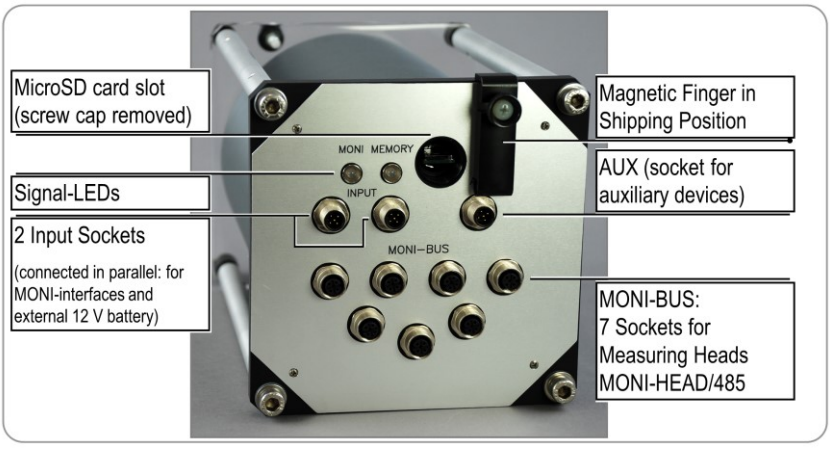


Fig. 6: MONI-DA Rear Face

5.1.3 MONI-DA, MONI-DA/S: Rear Face

Located on the back side of the data acquisition system are the signal LEDs, a memory card slot (not available for MONI-DA/S), a fixing screw for the magnetic finger and the connections for measuring heads, accessories and interface.

LEDs

The status of the MONI-DA is indicated by the MONI (Monitoring-LED) and the MEM LEDs (Memory-LED). The pair of LEDs is present on both the front and rear face in case of the MONI-DA. The MONI-DA/S possesses the LEDs only on the front face. See Table 3 for the LED codes.

MicroSD Card

By default, both, the MONI-DA and the MONI-DA/S are equipped with an industrial grade 0.5 GByte MicroSD flash card. The MONI-DA also handles 1 and 2 GByte MicroSD cards. For data transfer to a PC, plug in the MicroSD flash card of the MONI-DA in the card reader of your computer.

In the MONI-DA/S unit, accessing the MicroSD card requires opening of the housing: therefore, the card serves for backup of data. Download of data is described in Section 5.4.2 (page 30).

MicroSD Card Handling

Only high quality Industrial Grade MicroSD cards should be used for data storage. They need to be FAT16 formatted. The FAT32 format as well as SDHC and SDXC are not supported by the MONI-DA.

Do not remove or insert a memory card while writing or reading data that is shortly before, during, and shortly after saturation pulses. Also, do not remove the memory card during data restoration or formatting.

Table 3: Signal LEDs Modem

Status	Event	MONI (Monitoring-LED)	MEM (Memory-LED)
Start	Searching devices	Fast green flashes	Fast green flashes
	Detecting devices	Lights up red	Fast green flashes
Measure mode	Batch or clock running, and device detected	Double green flashes every 2 seconds	
	Batch or clock not running, and device detected	Single green flash every 2 seconds	
	No device detected = Searching devices	Fast green flashes	Fast green flashes
	Memory flash card ok		Double green flashes every 2 seconds
	Memory flash card error		Double red flashes every 2 seconds
	Writing to memory flash card		Fast green flashes
	Saturation pulse execution	Light constantly green	
Hibernation	Batch or clock running, and device detected	Double green flashes every 10 seconds	
	Batch or clock not running, and device detected	Single green flash every 10 seconds	
	No device detected	Double red flashes every 10 seconds	
	Memory flash card damaged		Double red flashes every 10 seconds
	Memory flash card ok		Double green flashes every 10 seconds

To remove a MicroSD card from the MicroSD card connector, gently push and release the SD card. Do not attempt to pull out the MicroSD card without prior unlocking it by a “push-to-release” action. Also, installing the MicroSD card requires push and release.

Memory cards have limited lifetime and should be replaced regularly. The lifetime depends on the number of storage processes.

Do not touch the contact area of the MicroSD card. When fingerprints or stains are found on the contact area, wipe the area with a soft dry cloth.

Magnetic Finger

The MONI-DA (also MONI-DA/S) is delivered with a “magnetic finger”. The magnetic finger is used to operate the MONI-DA via the 7 magnetic proximity switches at the MONI-DA front face (Fig. 8, page 21). For transport, the MONI-DA system can be completely switched off by placing the magnetic finger in the transport position at the rear face of the MONI-DA. In the off-state, signal LEDs do not flash.

Input and AUX Socket

Two parallel-connected input sockets and one AUX (auxiliary) socket are provided. All three are male M12 5-pole sockets in case of the MONI-DA but the MONI-DA/S uses special waterproof 6-pole sockets. Table 4 (page 20) summarizes the options for connecting various devices to the MONI-DA.

After a computer connection has been established using an interface (see Section 5.2), the standby mode of the MONI-DA is disabled, and the device is operated by the WinControl-3 software which also acquires all currently measuring data. In parallel, writing on the MicroSD card and in internal flash memory continues.

Note that the option to select different measuring light intensities for different MICRO-HEAD/3B is available only when the MONI-DA is operated in stand-alone mode. Operation by WinControl-3 will set measuring light intensities of all MICRO-HEAD/3B to the intensity level of the first detected MICRO-HEAD/3B.

The MONI-DA battery is charged via a RS 485 communication cable. For charging, the cable is plugged into one of the input sockets of the MONI-DA.

For powering the MONI-DA by an external 12 V battery, the relevant pins are marked in Fig. 7.

Table 4: Assignment of Input and AUX Sockets of MONI-DA

Socket / Device	Input 1 and 2	AUX
PC Interface Box MONI-IB1	yes	no
PC Interface Box MONI-IB4/LAN	yes	no
WiFi Modem/Satellite Modem	no	yes
Solar Panel SP	yes	yes
12 V External Battery	yes	no

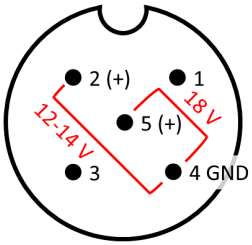


Fig. 7: Pin Assignment for Connection of External Power Sources to MONI-DA

View from the outside. To charge battery, use positions 4 and 5 of Input 1 or 2, or AUX. To connect an external battery, use positions 4 and 2 of Input 1 or 2. Compare Table 4.

MONI-Bus

The MONI-Bus consists of 7 female M12 5-pole sockets for communication with measuring heads MICRO-HEAD/3B (MONI-DA/S: 7 special waterproof 6-pole sockets for connection of MONI-HEAD/S).

5.1.4 MONI-DA, MONI-DA/S: Front Face

The front face of the data acquisition system contains the user interface consisting of a b/w display and a number of magnetic proximity switches. On the front face positioned is a fixing screw for the magnetic finger when the machine is in the acquisition mode.

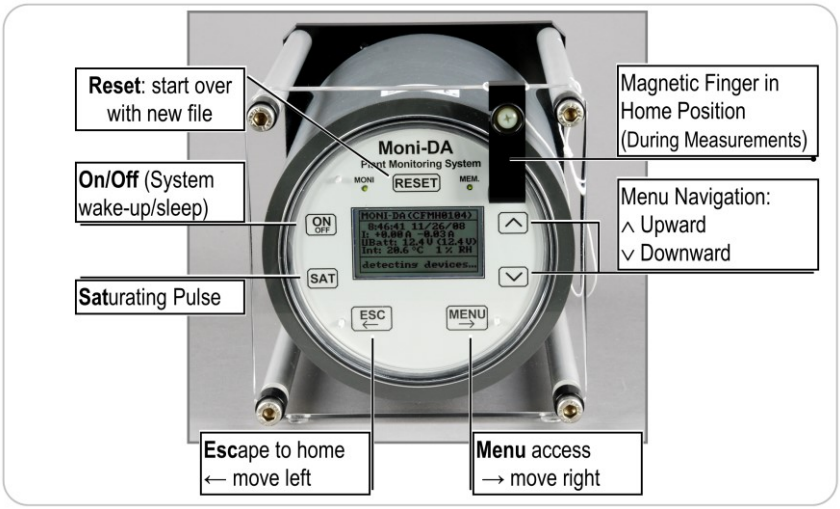


Fig. 8: MONI-DA Front Face

Magnetic Finger

During measurements, the magnetic finger is kept in the home position (see Fig. 8).

Control of the MONI-DA, MONI-DA/S

The MONI-DA can be configured using WinControl-3 software via an interface. A large number of commands and data, however, are directly accessible by the 7 magnetic proximity switches of the front plate. The option to adjust certain settings for different measuring heads individually is only available in the stand-alone mode of the MONI-DA, that is, in the absence of computer control.

To operate the proximity switches, hold the magnetic finger horizontally and move the rounded end of the finger vertically over the switch area. For instructions on operation see Section 5.3, page 25.

5.2 Interface Devices

5.2.1 PC Interface Box MONI-IB1

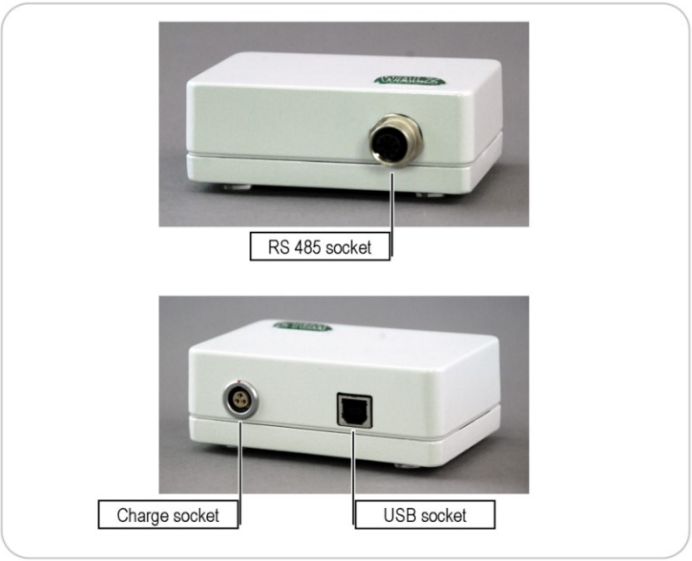


Fig. 9: PC Interface Box MONI-IB1

For online operation, the PC Interface Box MONI-IB1 connects the MONI-DA data acquisition system to a Windows computer (Fig. 5, page 13). The box is equipped with an RS 485 and a USB port (Fig. 9). When connected to a computer, the STAND-ALONE configuration is operated in online mode, that is, the software WinControl-3 controls the MONI setup and acquires data.

Data acquired in the stand-alone mode by the MONI-DA cannot be downloaded via the MONI-IB1 box. Instead, the MicroSD card in the MONI-DA must be readout. The MONI-IB1 box is also used to charge the MONI-DA battery.

5.2.2 Four-Way Distributor MICRO-HUB

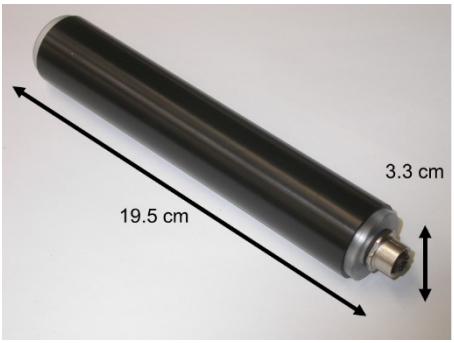
The MICRO-HUB enables to connect more than seven MICRO-PAM measuring heads to the data acquisition system MONI-DA. The maximum number of measuring heads per MONI-DA is 16 corresponding to 12 heads connected via MICRO-HUB and 4 directly connected heads.

Fig. 10: Four-Way Distributor MICRO-HUB

5.2.3 Wi-Fi Modem MONI-DA/WIFI

The Wi-Fi modem transfers data from the MONI-DA data acquisition system to a Walz server. The data can be downloaded from the server. The Wi-Fi modem requires network access or connection to a hotspot.

Fig. 11: Wi-Fi Modem MONI-DA/WIFI



5.3 MONI-DA Operation

Table 5: MONI-DA Operation

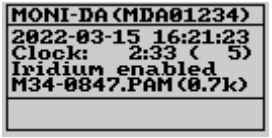
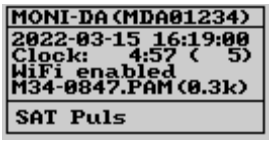
	KEY COMMAND	SCREEN	COMMENT
a	**RESET** Detects devices connected (here satellite modem) and starts a new data file on MicroSD card	**Home Screen** 	
b	**On/Off** ON switches the home screen on. OFF puts the MONI-DA into the standby mode	**Home Screen** 	
c	⮝/⮟ Starting from the home screen, the keys scroll through four pages (**d** to **f**, and **h**)		Pages accessible: Home Screen (see **d**) MONI-DA values (see **e**) Measuring Head values (see **f**) Fast Kinetics Screens (see **h**)
d		**Home Screen** 	**1st line.** Serial number of MONI-DA (in brackets) **2nd line.** Time & date **3rd line.** Time until next event (mm:ss); In clock mode: time till next flash & clock interval. In batch mode: time till next flash **4th line.** Display of device connected (here Wi-Fi modem) **5th line.** File name, file size **6th line.** Message row

Table 5: MONI-DA Operation

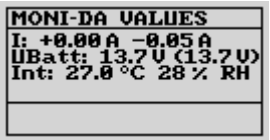
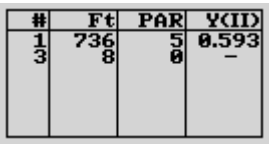
	KEY COMMAND	SCREEN	COMMENT
e		**MONI-DA Values** 	**1st line.** Screen title **2nd line.** Charging & consumption current **3rd line.** Battery voltage during measurement and saturation pulse (bracketed) **4th line.** Temperature & relative humidity inside MONI-DA
f		**MONI-HEAD Values** 	**Column Content** **#** Measuring Head ID **Ft** Fluorescence level **PAR** Photosynthetically active radiation, µmol/(m²·s) **Y(II)** Effective photochemical quantum yield of photosystem II
g	➢ and "MONI-HEAD Values" screen displayed (see **f**)	**PAM Settings** 	**1st line.** Screen title **2nd line.** Key ➢ followed by ➢ and ➢ keys adjust saturation pulse length. Key ➢ escapes. **3rd line.** Keys ➢ and ➢, selection of "Yes" by ➢ followed by ➢ restores factory settings in all measuring heads

Table 5: MONI-DA Operation

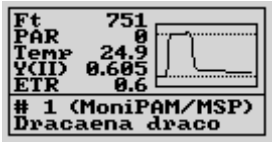
	KEY COMMAND	SCREEN	COMMENT
h	Use ⮝ and ⮟ key to select MONI-HEAD **SAT** and "Fast Kinetics" displayed triggers a saturation pulse only in the measuring head selected **SAT** triggers a saturation pulse in all measuring heads when "Fast Kinetics" is NOT displayed	**Fast Kinetics** 	**Ft, PAR, and Y(II):** see **f** **Temp:** Temperature **ETR:** Electron transport rate **Last two lines:** Device number and microprocessor typ. Comment written in WinControl-3 **Graph:** Fluorescence trace during saturation pulse
i	➢ and "Fast Kinetics" screen (**h**) displayed	**MONI-HEAD Settings** 	**1st line.** Measuring Head ID **2nd line.** Intensity setting of PAM excitation light. To adjust, use key ➢ followed by ⮝ and ⮟ keys. Key ➢ escapes **3rd line.** Amplification factor. To change use keys ⮟ and ➢ and subsequently the ⮝ and ⮟ keys **4th line.** Automatic determination of background signal. To determine background signal, direct optical window away from objects and light sources, select Auto Offset by ⮟ and ➢, and choose Yes (⮟ and ➢) **Ft** and **Offset** are the currently measured fluorescence level and the currently used background signal, respectively

Table 5: MONI-DA Operation

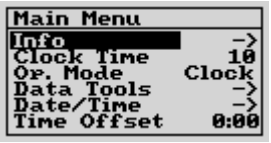
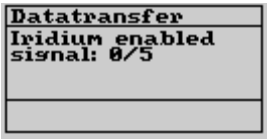
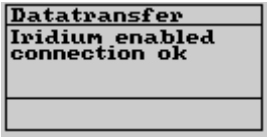
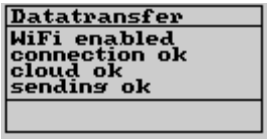
	KEY COMMAND	SCREEN	COMMENT
j	➢ (Menu) and home screen (**a**) displayed, or ➢ (Menu) and MONI-DA values (**e**) displayed To navigate, use up/down (⮝ ⮟) and left/right (⮜ ➢) buttons	***Main Menu***  ** In the batch mode, the MONI-DA is controlled by the currently loaded batch file (see . Section 6.2.5, page 58)* *** UTC=Coordinated Universal Time. "Time Offset" determines the time stored on flash memory, and the time displayed. UTC is used for internal data processing.*	**1st line.** Screen title **2nd line.** Access to MONI-DA firmware and flash memory information: Revision number and date, flash memory size in data sets, and operating hours **3rd line.** Adjustment of intervals between saturation pulses **4th line.** Setting of saturation pulse control: either clock or batch mode***** **5th line.** Opens menu Data Tools (see **k**) **6th line.** Setting date and time **7th line.** Offset relative to UTC******
k	To navigate, use up/down (⮝ ⮟) and left/right (⮜ ➢) buttons	**Data Tools** 	**1st line.** Screen title **2nd line.** Displays signal strength detected by modem **3rd line.** Tests data transfer by modem **4th line.** Writes data from internal memory to MicroSD card. Capacity: 10 days with 4 measuring heads and clock interval of 5 minutes **5th line.** To FAT16 format a MicroSD card

Table 5: MONI-DA Operation

	KEY COMMAND	SCREEN	COMMENT
l	➢ and "Sig. Indicator" selected	 	**Satellite Modem** Relative signal strength. 0, n signal. 5, high signal strength. **Wi-Fi Modem** Signal strength. -30 dBm, maximum. -60 to -67 dBm, fair. -80 dBm, check network.
m	➢ and "Test Transfer" selected	 	**Satellite Modem** Checks satellite connection. **Wi-Fi Modem** Checks the following. Connection, connection to network. Cloud, connection to server. Sending, acceptance of data by server.

5.4 Data Storage and Transfer

5.4.1 MicroSD Card

By default, both, the MONI-DA and the MONI-DA/S are equipped with an industrial grade 0.5 GByte MicroSD flash card. The MONI-DA also handles 1 and 2 GByte MicroSD cards. For data transfer to a PC, plug in the MicroSD flash card of the MONI-DA into the card reader of your computer.

When the MicroSD card is removed and plugged back, the MONI-DA will resume writing on the last data file. Saturation flash data in the absence of a card can be retrieved from the MONI-DA internal flash memory (see Section IV). New data files are created with each clock start or by a system reset.

Data transfer from memory card to computer requires removal of the MicroSD memory card and readout using the card reader of a computer. Alternatively, data can be read from an internal flash memory chip (see next, Section 5.4.2).

5.4.2 Internal Flash Memory Chip

Properties

Parallel to saving data on MicroSD, data are stored on an internal 2, 4, or 8 Mbyte flash memory chip, depending on the version of MONI-DA (MONI-DA/S). The flash memory acts as ring buffer which means that, once filled, the latest data overwrites the oldest ones.

Flash Memory Size

The “Info” page of the MONI-DA menu indicates the size of the flash memory chip as maximum number of “data sets” that can be stored. Per saturation flash analysis, one data set is created by the MONI-DA and also one data set per each of the measuring heads connected to the MONI-DA. The relationship between flash memory sizes in Mbyte and data sets is given in Table 6:

Table 6: Internal Flash Memory

Size of flash memory chip, Mbyte	Maximum data sets
2	12000
4	28000
8	60000

The maximum available experimental time can be assessed according to:

$$\text{Time}_{max}[\text{days}] = \frac{\text{Memory Size [data sets]} \cdot \text{Clock Interval [min]}}{1440 \cdot (\text{Number of Measuring Heads} + 1)}$$

The same equation can be used to assess the capacity of MicroSD cards which usually can hold data of many years but will stop storing data when full.

Preparations for data transfer

Connect data acquisition unit and PC interface.
Terrestrial: MONI-DA ←→ MONI-IB1 or MONI-IB4/LAN.
Aquatic: MONI-DA/S ←→ MONI-IB1/S or MONI-IB4/LANS.

Connect PC interface box and computer.

Make sure that WinControl-3 is installed on the computer. The installation process provides the interface drivers for data transfer. Make sure that WinControl-3 is closed.

The software **bustool.exe** is provided on the Walz USB flash drive. It can also be downloaded from the Walz website.

Copy **bustool.exe** to a folder where you have permission to download MONI-DA(/S) data. Do not select the root of the C drive, it is protected by Windows.

In Windows Explorer, click on the folder containing the bustool software. Then, click on the empty space in the Windows Explorer

address bar (right of the folder address). The entire folder address should now be highlighted. Type **cmd**. The command prompt window opens with the bustool folder already selected.

Bustool commands

To list all data files in flash memory, type: **bustool -a 0 -l** (bustool, space, minus letter a, space, number zero, space, minus letter l) and hit the enter key. The **-a** followed by **0** specifies the device address which is always zero in the case of the MONI-DA, and the **-l** is the list command.

The file list appearing in the command prompt window contains the information specified in Table 7:

Table 7: File Information

id	measurement start	measurement start	file size	filename	comment
MONI-DA file number	date	Time	number of data sets	file name	incomplete file note
`integer`	`yyyy-mm-dd`	`hh:mm:ss`	`integer`	`Mss-iiii.PAM` where `ss` = MONI-DA device number and `iiii` = consecutive file counter	`(partial)`

Note: the number of data sets per saturation pulse analysis is 1 + the number of measuring heads connected to the MONI-DA. The comment "(partial)" indicates that the file is incompletely present because it has been partially overwritten by newer data.

To download the file with the MONI-DA id number **X**, type **bustool -a 0 -d X** and press the enter key. The command downloads file **X** into the directory in which bustool.exe is located. Communication has been optimized to work properly even for long data lines: therefore, a Baud rate of 19200 was selected which corresponds to about 5 data sets per second.

Help

Type **bustool -h** and enter key

Delete: files on the flash memory cannot be deleted. Oldest data will be automatically overwritten by the newest ones.

5.4.3 Network connection via Ethernet

Connections

Connect MONI-IB4/LAN to a network, thereafter, connect line power.

Find IP address/DHCP host name

The DHCP hostname and Hardware Address are printed on the MONI-IB4/LAN. The DHCP hostname is identical to the serial number (S/N) and has the format CFMIXXXX (the X stands for Arabic numerals. MONI-IB4/LANS: CFMMXXXX).

Start network mode of WinControl-3

Click on Windows Start button.
Select Programs and WinControl-3.
Select WinControl-3 Network Mode.

Now the Network connect window appears. Enter the DHCP host name and click OK. The connection to the PAM device will be established.

Fig. 12: Network Connect Window

The IP address also can be entered in the Network connect window but only the DHCP host name provides a permanent address

when different IP addresses are assigned to the MONI-IB4/LAN by the DHCP server.

Find MONI-IB4/LAN addresses

In case the procedure described above was not successful, you can check the address of the MONI-IB4/LAN as described next:

Download from DeviceInstaller program from Lantronix webpage: https://www.lantronix.com/products/deviceinstaller/ (Note that the DeviceInstaller requires the Microsoft .NET framework which is present on up-to-date computers but is also available via the Lantronix webpage.

Install and launch DeviceInstaller. The MONI-IB4/LAN should now appear as XPort with IP and hardware address (Fig. 13).

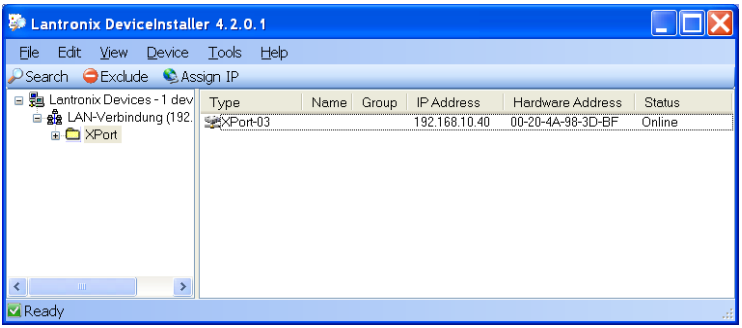


Fig. 13: DeviceInstaller 1

Click on XPort until the right window displays the “Device Details”, “Web Configuration” and “Telnet Configuration” tabs (see Fig. 14).

Select <Web Configuration> and navigate to XPort by clicking the white arrow (→) on green background.

Hit <Enter> key to ignore the User/Password window.

Click <Network> on the XPort window (upper left corner).

The next window shows the DHCP host name of MONI-IB4/LAN.

If network connection with new address information still cannot be established, contact your network administrator to assign an IP address manually using the <Assign IP> function of the DeviceInstaller software.

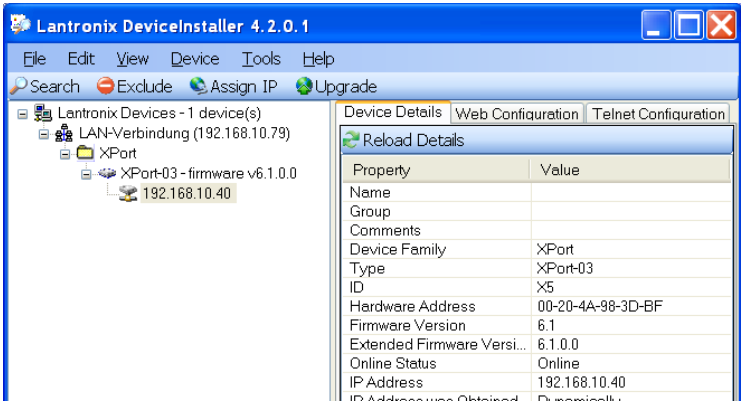


Fig. 14: DeviceInstaller 2

5.4.4 WinControl-3

The MONI-DA can be operated under WinControl-3 using a PC interface. When controlled by WinControl-3, the magnetic proximity switches of the MONI-DA are unresponsive except the RESET button.

In WinControl-3, information on MONI-DA and connected devices are displayed in the MONI-Bus window of WinControl-3. Data on the MONI-DA can be viewed under settings when MONI-DA is selected in the device drop-down list (upper left corner of settings window). Similarly, physical information on devices connected to the MONI-DA can be retrieved by selecting the device in the device drop down list.

5.5 Modem

5.5.1 Download MONI-DA Data

Wireless transfer of MONI-DA data can be carried out via Wi-Fi or Iridium satellite modem. Data transfer is also performed by the earlier GPRS modems which are no longer produced.

In all cases, a Walz server receives the MONI-DA data. Walz provides account name and access code to download your data. The server's URL is https://www.pam-monitoring.com/. Fig. 15 displays the welcome window of the Walz server.

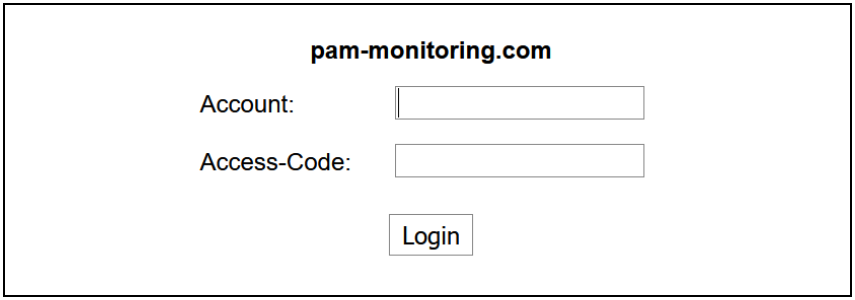


Fig. 15: Login to Walz Server

After login, the server displays the MONI-DA download window (Fig. 16). The window shows the name(s) of your measuring site(s), the current date and time, and the period elapsed since the last data transfer. The period is given in units of m (minute), h (hour), d (day), or y (year). The elapsed period is additionally indicated by a color code, where green indicates normal traffic.

The download window provides a command to display the last 24 hours of data on a chart. Commands to download the last 24 hours or the last year of data are also available. The calendar icon allows you to select any download time interval.

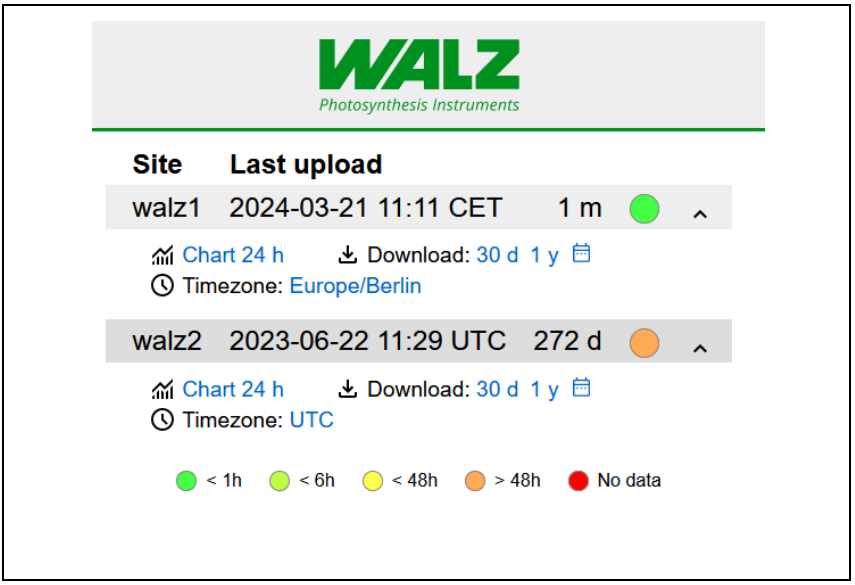


Fig. 16: Data Information on Walz Server

5.5.2 Wi-Fi Modem Upload

Connect Wi-Fi modem to the AUX port of the MONI-DA, and MONI-DA to computer. The modem is automatically detected by the MONI-DA. The Wi-Fi/GPRS area on the Settings window of WinControl-3 has four input fields (Fig. 17 and Table 8). The Walz server information (Account and Access Code) is preprogrammed and should automatically appear. If this information is absent, enter the access information provided by Walz. SSID and key are properties of the Wi-Fi network or the hotspot. Check data transfer using the MONI-DA screen (Table 5, l and m).

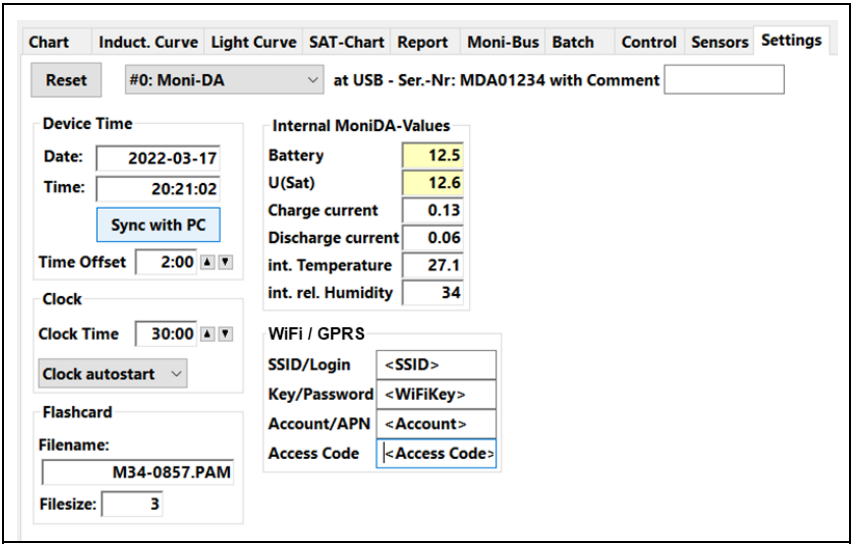


Fig. 17: Modem Settings

Table 8: Login Information

	WiFi	GPRS
SSID/Login	SSID: Access data of Wi-Fi network.	Login: As instructed by your SIM card provider.
Key/Password	Key: Access data of Wi-Fi network.	Password: As instructed by your SIM card provider.
Account/APN	Account: Access data of Walz server	APN (access point name): As instructed by your SIM card provider.
Access Code	Access Code: Access data of Walz server	

5.5.3 GPRS Modem Upload

The production of GPRS modems has ceased. The instructions given are for users having acquired the GPRS modem earlier.

5.5.3.1 Cost Considerations

At each saturation flash analysis, the GPRS modem sends data of the previous saturation flash analysis. The data files sent are rather small. Typically, one set of saturation pulse data of a MONI system comprising six measuring heads corresponds to about 1 Kbyte; the amount of data varies roughly proportionally with the number of measuring heads of the MONI system.

GPRS providers offer flat rates or they charge according to the amount of data transferred. In the latter case, the total amount of data is calculated as the sum of packages of definite size, that is, always the complete package size will be added even if the actual size of data transferred is smaller than the package size.

Let us consider that a GPRS provider uses a rather small package size of 10 Kbyte. This package size is clearly greater than the saturation pulse data of even complex MONI systems. If saturation pulse analyses are carried out every 10 minutes, the data size per month is

10 Kbyte · (6·24 packages/day) · 30 days = 43 Mbyte

Hence, a contract for 50 Mbyte per month would be sufficient to cover the data transfer of 43 Mbyte calculated above. Often, the minimum total transfer volume of GPRS providers is 100 Mbyte. Still, these 100 Mbyte might be cheaper than GPRS flat rates.

5.5.3.2 Operation

The Walz GPRS modem uses serial data transfer to communicate with the MONI-DA. For insertion or replacement of the SIM card, the weatherproof case of the modem has to be disassembled as described overleaf. Standard SIM cards (“Mini-SIM”) can be used in the modem. Also, Micro- and Nano-SIM-cards can be employed using appropriate adapters.

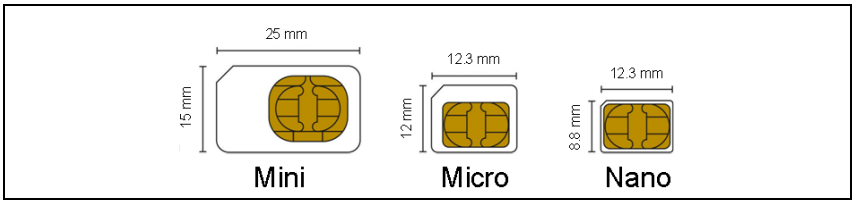


Fig. 18: SIM Cards

Any PIN code protection of the SIM card needs to be inactivated before the SIM card is installed in the GPRS modem. To inactivate the PIN code, insert SIM card in a suitable mobile phone and proceed as described in the phone’s manual.

To mount the SIM card, unscrew the four hex head screws at the front panel which holds the connectors and the status LED (cf. drawing). Carefully draw out electronics. Pay attention to keep the two gaskets of the front plate in place (Fig. 19).

The main circuit board holds a smaller board which contains the modem as well as the SIM card slot (drawn in red, Fig. 19). To install a SIM card, simply push the card into the slot and release. To remove SIM card, gently push and release card. Do not attempt to pull out the SIM card without prior unlocking by a “push-to-release” action.

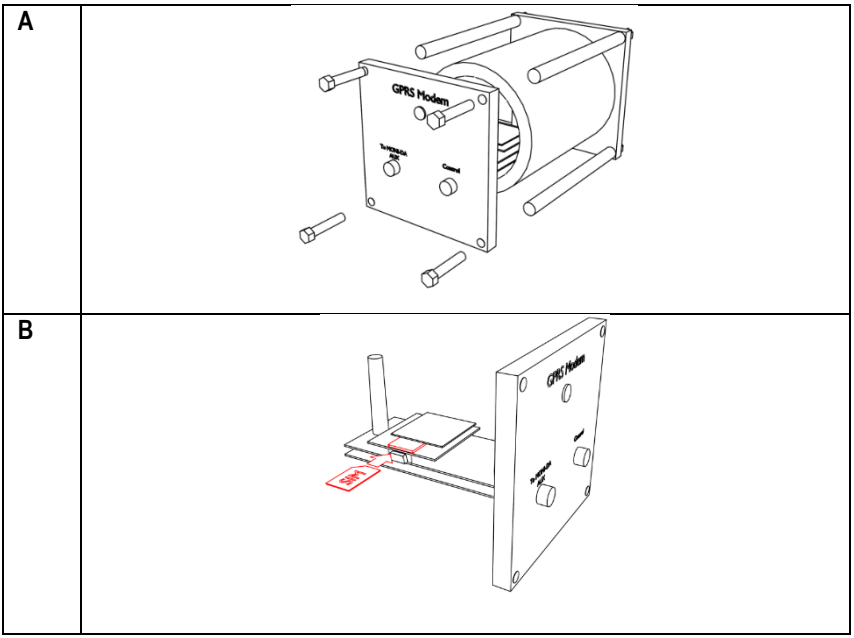


Fig. 19: SIM Card Mounting

A, opening of GPRS modem housing. B, insertion of SIM card

To establish the GPRS connection, connect GPRS modem to AUX port of the MONI-DA, and connect MONI-DA to computer. To connect, only three input fields of the Wi-Fi/GPRS area have to be filled in: Login, Password, and APN (Fig. 17 and Table 8). This data are delivered with the GRPS service of your provider.

5.5.4 Satellite Modem

Connect satellite modem to the AUX port. The satellite modem is fully preprogrammed (Including “International Mobile Station Equipment Identity”, IMEI) and the Wi-Fi/GPRS area has no entries. Test data transfer as instructed in Table 5, sections l and m.

6 WinControl-3 Software

6.1 WinControl-3 Installation

The WinControl-3 software is provided on a Walz USB flash drive. The WinControl-3 software is regularly optimized. The latest software version is available on the Walz website:

https://www.walz.com/products/chl_p700/micro-pam/downloads.html

WinControl-3 can be installed from the Walz USB flash drive or using the setup software downloaded from the Walz website.

6.1.1 Installation process

The installation of WinControl-3 is mostly automatic. Dialog boxes appearing during setup provide advice or allow configuration of WinControl-3. To install WinControl-3, proceed as follows:

- Close other programs as advised by the setup wizard.
- Execute setup file: double-click on file or right-click on file and choose “run” from context menu.
- A pop-up windows must appear which identifies the Heinz Walz GmbH as a verified publisher.
- Accept default folder for program installation or choose different folder after clicking Browse… .
- Select “Standard” Installation. (The “JUNIOR-PAM Teaching Edition” runs only with JUNIOR-PAM fluorometers.)
- Install USB driver and select optional WinControl-3 links (icon or shortcut).

- Connect MONI-DA to computer and run PAM Firmware Update. If the current firmware* is outdated, PAM Firmware Update will automatically replace it with the recent version. Running PAM Firmware Update after installation of WinControl-3 is important because new software properties may function only in the presence of the latest firmware.
- Connect MICRO-HEAD/3B to computer and run PAM Firmware Update. Measuring heads must be connected via interface (MONI-IB4/LAN or MONI-IB4/LAN) to the computer. Firmware update does not work when the MICRO-HEAD/3B is connected to the MONI-DA.

*The term firmware denotes a piece of software residing on a flash memory of the MINI-PAM-II. Newest firmware is delivered as part of the WinControl-3 software.

Table 9: WinControl-3 in Windows Start Menu

 WinControl-3
 PAM Firmware Update
 Uninstall WinControl-3
 WinControl-3
 WinControl-3 – Network Mode
 WinControl-3 – Offline

6.1.2 WinControl-3 Program Group

Setup of WinControl-3 creates the WinControl-3 program group (Table 9, p. 44) in the Windows Start menu. The 5 items of the WinControl-3 program group are.

(1) PAM Firmware Update

Initialization of PAM Firmware Update triggers a search for PAM devices connected to the computer. The result is displayed in the right panel of window “Devices” (Fig. 20, page 46). Each device name is preceded by its address number (between hash and colon).

“PAM Firmware Update” compares the firmware in the device with the firmware included in the WinControl-3 software. If WinControl-3 includes newer firmware, the device is automatically updated.

“PAM Firmware Update” cannot update firmware of first-generation devices (DIVING-PAM, MICROFIBER-PAM, MICROSCOPY-PAM, MINI-PAM, WATER-PAM). In these devices, firmware resides on an EPROM chip and firmware update requires exchange of this chip.

A device can be selected by mouse click. The currently selected device is highlighted (white letters on blue background). The main panel of the window shows information on the device selected. The first four information lines define the hardware and software state of the device. The last line displays a comment associated with the device and typed in using the WinControl-3 software.

Devices with identical addresses cannot be operated simultaneously. If WinControl-3 detects identical addresses, the window “Device Channel Configuration” (Fig. 21, page 47) pops up offer-

ing a working address configuration and the option to change addresses manually. Note that address number is synonymous to channel number in the software WinControl-3.

Address numbers can be changed manually via the button change address. Then, determine new address by picking a number from the drop-down list “New address:”. If several devices are connected, the drop-down list offers only unused address numbers.

The window “Messages” displays the protocol of activities including firmware update of devices. The window “Firmware Versions” compiles all software version provided by PAM Firmware Update.

(2) Uninstall WinControl-3

This program removes WinControl-3 and all its links. It does not remove the USB driver software.

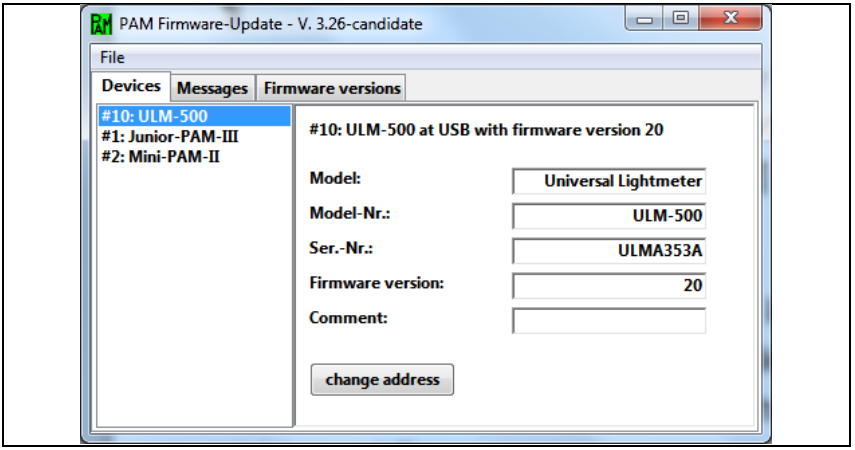
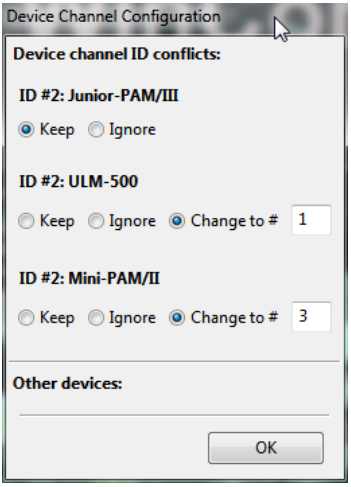


Fig. 20: PAM Firmware Update
Several devices connected to the same computer must have different addresses (channel numbers).

Fig. 21: Device Channel Configuration



(3) WinControl-3

Subfolder “WinControl-3” starts WinControl-3 in the default mode. When devices which are compatible with the WinControl-3-type software are detected, WinControl-3 enters the measure mode. Clicking Offline-Mode interrupts the search process and WinControl-3 is started in the offline mode. When the search process fails to find compatible devices, a pop-up window provides three options: Yes triggers another search for devices, No launches the offline mode of WinControl-3, and Cancel ends the whole process. Measuring mode and offline mode, and several instances of WinControl-3 in the offline mode, can run in parallel.

After detection of the devices, measuring of fluorescence is automatically started. To continuously display the fluorescence signal (Ft), check “Rec. Online” or click Start Online. If the Ft is much lower than 250, check leaf position and increase measuring light intensity and/or gain. Click Autoscale if data are not visible. Trigger saturation pulse analyses by pressing Fo, Fm or SAT A healthy leaf, which was kept dark before, should show a value for F_V/F_M of 0.8 or higher.

(4) WinControl-3 Network Mode

See 5.4.3, page 33.

(5) WinControl-3 Offline Mode

This command launches Wincontrol-3 without the initial search for available PAM devices.

6.2 WinControl-3 Operation

Launch software via desktop icon or the WinControl-3 folder in the Start menu of Windows. The software will automatically detect all devices connected and being compatible with the WinControl-3 software. The following section will provide an overview on the operation of a MICRO-PAM system by WinControl-3. More details are available in the latest edition of the Manual for the MINI-PAM-II.

https://www.walz.com/products/chl_p700/mini-pam-II/downloads.html

6.2.1 Chart Window

The Chart window (Fig. 22) continuously records PAM fluorescence (Ft) and the results of saturation pulse analysis. The amount of data produced by a MICRO-PAM system can be overwhelming. To get an overview, reduce the number of data displayed by selecting parameters on the “Val.” panel, or by selecting channels on the “Rec.” panel or by both.

In the same way, data display can be controlled in other windows (Induct. Curve, Light Curve, and Report). In the latter case, the data selection also corresponds to the data exported as CSV file.

On the chart, an X axis interval can be marked by the cursor with the left mouse button pressed. A right click in the marked area opens a context menu. All marked data are also highlighted in the SAT Chart window and the Report.

Table 10 summarizes and explains the commands of the Chart Window.

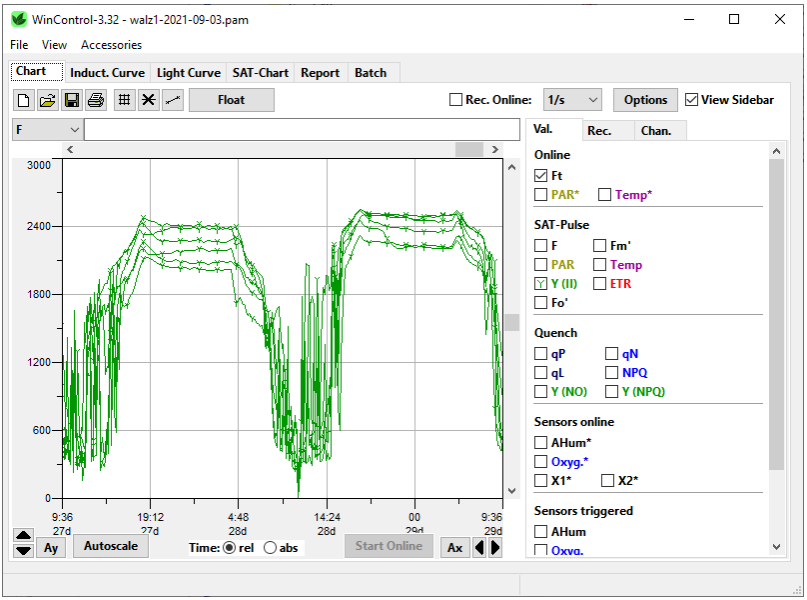


Fig. 22: Chart Window

Table 10: Chart Commands		
Icon	**Command**	**Comment**
	Delete	Delete current data (all records and report data)
	Load	Delete current data and load previously saved data. Same function as Load Data in File menu.
	Save	Save all records of the current experiment. Same function as Save Data in File menu
	Print Chart	Print current chart
	Switch Grid on/off	Graph design command
	View Symbols on/off	Graph design command
	View Lines	Graph design command
Float	Float	Create a floating chart window. Graph settings and data selection of the new chart are independent of the WinControl-3 main window.
☑ Rec. Online	Record Online	Record continuously Ft, PAR* and Temp*. For long-term measurements, Rec. Online may be turned off when memory size is small.
5/s	Sampling Frequency	Dropdown menu with three different sampling frequencies for online record: <5/s>, <1/s>, and <1/10s>. The frequency setting affects only online data (Ft, PAR*, and Temp*, see below). The highest sampling frequency of <5/s> applies only to Ft: sampling of PAR* and Temp* occurs with <1/s> maximally. The actual intervals between measurements vary depending on communication between fluorometer and computer.

Table 10: Chart Commands		
Icon	**Command**	**Comment**
Options	Options	Menu with 4 items of which two (Zoom to Selection and Export Selection) are available only after chart data have been selected. To select data, place mouse cursor in the Chart area, move mouse cursor with left mouse button pressed parallel to the x-axis across the data of interest: the selection will be highlighted. The options menu is also available by placing the cursor within the selected area and clicking the right mouse button. A single left-button click in the chart area removes an existing selection. Note that a selection made in the chard highlights the associated data in the SAT-Chart and the Report windows.
Export All	Export All	Export all data currently graphed (online and saturating pulse analysis data) as CSV file.

6.2.2 Moni-Bus Window

The Moni-Bus Window provides an overview to all devices connected to the MICRO-PAM (Fig. 23).

(p. 52) depicts the situation of 6 measuring heads connected to a MONI-DA. The numbers preceded by a hash in column 1 are channel numbers. Graphical and numerical data in WinControl-3 are always associated to the channel number.

The second column (Comment) can be edited. These comments are stored in the MICRO-PAM flash memory.

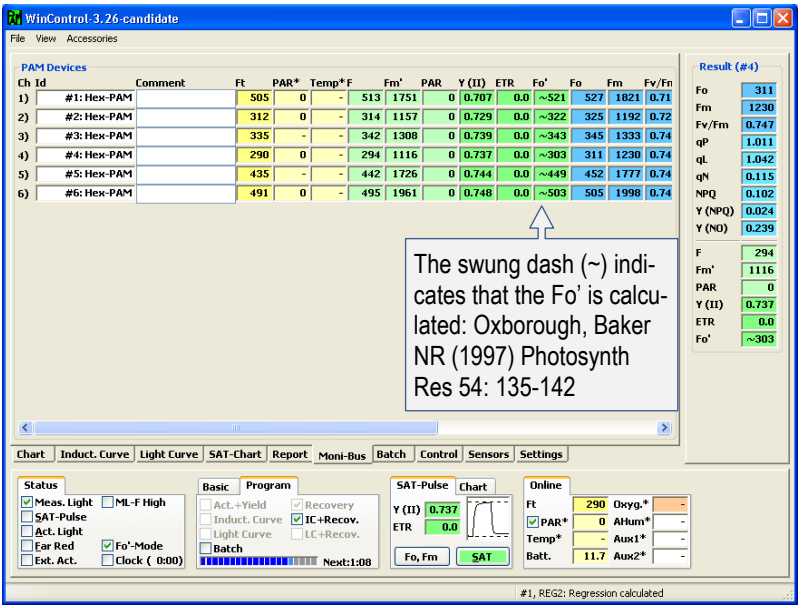


Fig. 23: Moni-Bus Window

Screenshot taken with predecessor model HEX-PAM.

6.2.3 SAT Chart Window

The SAT chart window displays fluorescence kinetics of the current experiments. In saturation pulse analysis, the F_M and F_M' levels are determined as the maximum of these curves. Factory settings of saturation pulse width and intensity are adjusted reach a plateau with normal green leaves (Fig. 25A). Some samples do not reach a plateau with standards settings (Fig. 25B). In this case, the saturation pulse intensity or/and length should be increased. Also, fluorescence kinetics can reach a maximum clearly before the end of the saturation pulse (Fig. 25C). This does not result in erroneous F_M or F_M' values because these values correspond to the maximum of fluorescence kinetics. In this case, saturation pulse intensity or/and length might be decreased.

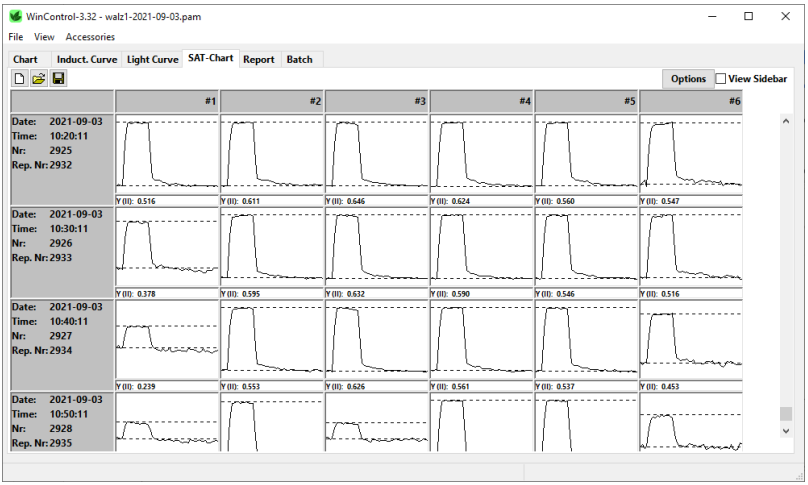


Fig. 24: SAT Chart Window

Some samples, particularly low light grown or senescing plants, exhibit somewhat decreased F_V/F_M values with standard settings but show normal fluorescence kinetics. These samples increase the F_V/F_M with decreasing saturation pulse intensity. Therefore, testing the F_V/F_M at saturation pulse intensities below (and above) standard settings is worthwhile to optimize your saturation pulse settings.

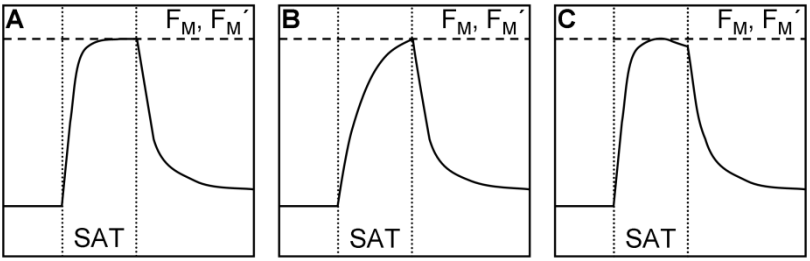


Fig. 25: SAT Pulse Kinetics

SAT pulse length is fine (**A**), too short (**B**), too long (**C**).

6.2.4 Light Curve Window

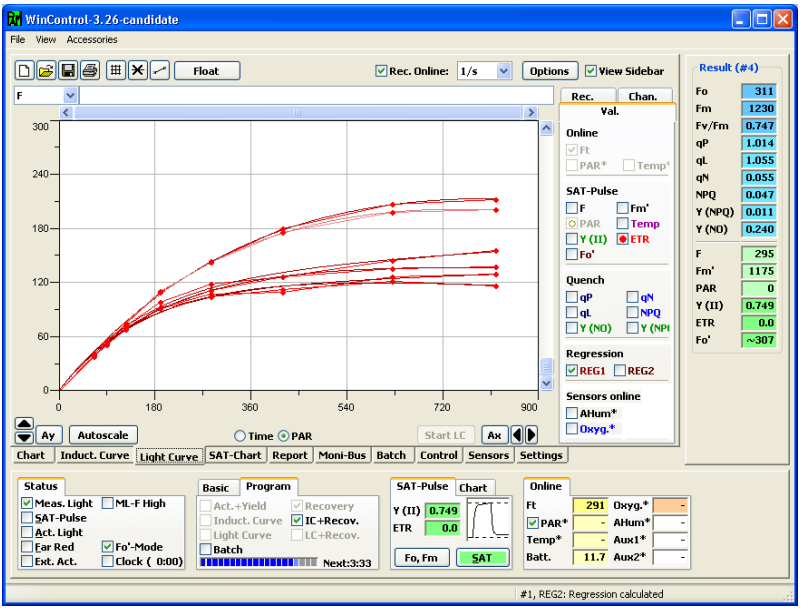


Fig. 26: Light Curve Window

Screenshot taken with predecessor model HEX-PAM.

The Light Curve window provides the button to start a light curve and to view the results of saturation pulse analysis plotted against PAR (Fig. 26, p. 54). The experimental course of a light curve is defined on the settings page.

A light curve program exposes a sample to stepwise increasing intensities of actinic illumination. In “Rapid Light Curves” (RLC), the time interval of each light step is short (down to 10 s) and full equilibration of photosynthetic reactions is not reached within an illumination interval. Typically, the RLC starts at a PAR value somewhat below that of the natural environment. RLC measurements are carried out with samples in their momentary acclimation status, that is, without dark-acclimation period to determine F_0 and

F_M. This way, RLC data can provide information on the present acclimation state of photosynthesis. Obviously, without F_0 and F_M determination, those fluorescence ratio parameters requiring F_0 and F_M (like NPQ) are not available.

If illumination steps are long enough to reach steady state of photosynthesis, fluorescence-based light curves may be compared with classical light response curves (P-I curves).

6.2.4.1 Light Curve Theory

The Light Curve window allows fitting model functions to experimental data. The experimental data are the electron transport rates (ETR) plotted against the photon flux density, PAR. WinControl-3 provides two model functions called REG1 and REG2 which are introduced in Fig. 27 and Fig. 28, respectively. The function REG1 can decrease at high PAR values. Therefore, REG1 can consider photoinhibition of photosynthesis, where β is a photoinhibition parameter. In contrast, REG2 is a rectangular hyperbola which cannot describe photoinhibition.

Both models calculate the three cardinal parameters of a light curve:

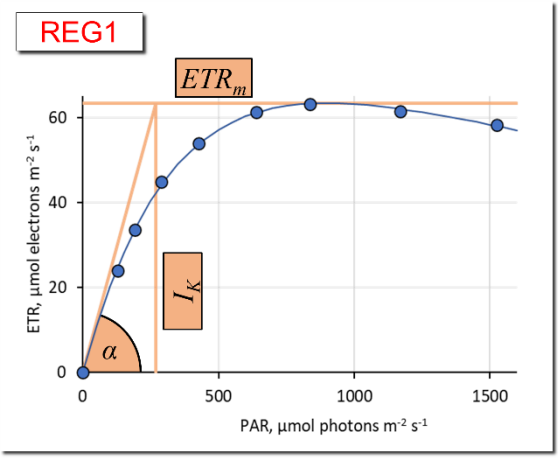
(i) α, electrons/photons: Initial slope of RLC which is related to the quantum efficiency of photosynthesis.

(ii) ETR_m, µmol electrons $m^{-2}{\cdot}s^{-1}$: Maximum electron transport rate.

(iii) I_K, µmol photons $m^{-2}{\cdot}s^{-1}$: Idealized PAR value at which light-limited photosynthesis becomes light-limited.

The cardinal parameters are written into the Report. To export cardinal parameters separately, right click on the chart of the

Light Curve window and select from the menu “Export Regression Data”.



$$ETR = ETR_{mPot} \cdot (1 - e^{-\frac{\alpha \cdot PAR}{ETR_{mPot}}}) \cdot e^{-\frac{\beta \cdot PAR}{ETR_{mPot}}}$$

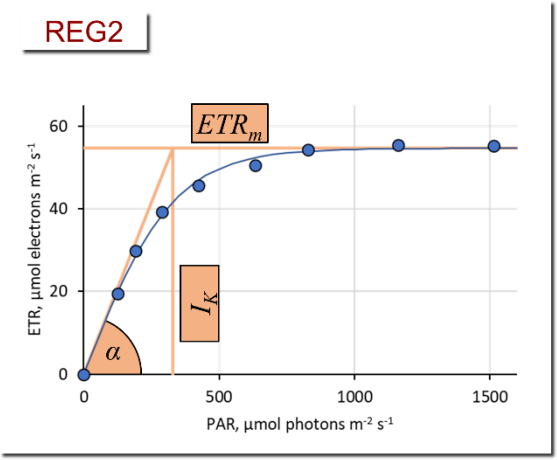
$$ETR_m = ETR_{mPot} \cdot (\frac{\alpha}{\alpha + \beta}) \cdot (\frac{\beta}{\alpha + \beta})^{\frac{\beta}{\alpha}}$$

$$I_K = \frac{ETR_m}{\alpha}$$

$$I_b = ETR_{mPot} / \beta$$

Fig. 27: Model Function REG1

The three cardinal points of the light curve are indicated (α, ETR_m, and I_K). The decrease at PAR>1000 µmol m^{-2} s^{-1} is frequently attributed to photoinhibition of photosystem II by strong light. I_b is the theoretical PAR at which the light curve reaches 1/e of ETR_{mPot}. ETR_{mPot} is the ETR_m in the absence of photoinhibition. According to: Platt T, Gallegos CL, Harrison WG (1980) Photoinhibition of photosynthesis in natural assemblages of marine phytoplankton. J Mar Res 38: 687-701



$$ETR = ETR_m \cdot tanh(\frac{\alpha \cdot PAR}{ETR_m})$$

$$I_K = \frac{ETR_m}{\alpha}$$

Fig. 28: Model Function REG2

The three cardinal points of the light curve are indicated (α, ETR_m, and I_K). According to Jassby AD, Platt T (1976) Mathematical formulation of the relationship between photosynthesis and light for phytoplankton. Limnol Oceanogr 21: 540-547.

6.2.5 Batch File Window

Batch files automatically execute experimental procedures. To activate the Batch window, click icon new batch or open existing batch file (Fig. 29, “Batch Start Buttons”). The click Edit and choose between “Add command” and “Record Macro”. The command “Update indentation” is an automatic editing tool to improve readability.

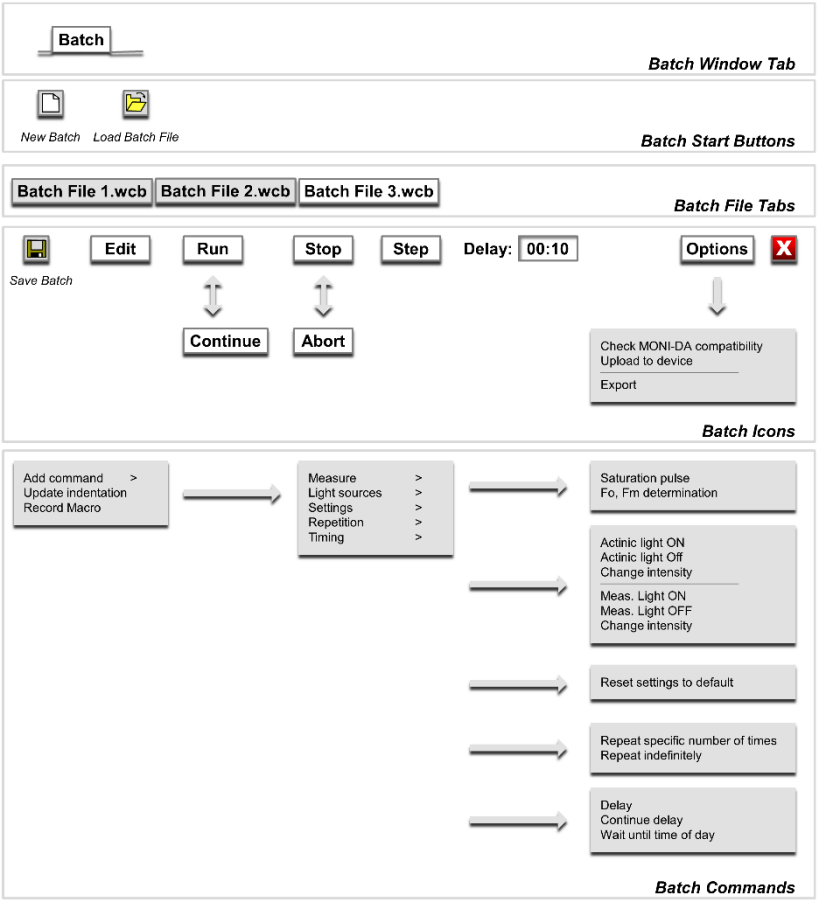


Fig. 29: Batch Window Overview

6.2.5.1 Add Command

Add command leads to five groups of commands (Fig. 29). A command can be inserted into a batch file by left-click.

Measure commands

Saturation pulse	Saturation pulse analysis of light-exposed sample
Fo, Fm determination	Saturation pulse analysis of dark acclimated sample

Light Sources commands

Controls for actinic and measuring light. The light ON command asks for the light intensity: simply enter the light intensity setting in the grey-shaded field. New intensity settings can be chosen using the commend “Change intensity”.

Settings commands

“Reset settings to default” installs default setting.

Repetition commands

The group contains two commands. “Repeat specific number of times” and “Repeat indefinitely”. Both commands write two lines on the batch file sheet. In case of the first command, these lines are:

Line 1:

```
for $loopvar = 1 to count // Start repetition block with specified number of repetitions
```

Line 2:

```
next                      // End of repetition block
```

Write commands to be repeated between Line 1 and 2. Define how often the commands should be repeated by the number entered in field count. The second command (Repeat indefinitely)

repeats the commands placed between the two lines until the batch program is stopped manually.

Timing

The command “Delay” inserts a time interval after the previous command has been terminated. The next command is executed when the time interval ends.

The command “Continue Delay” takes the end of the previous delay phase as starting point. Actions within this time interval are performed without affecting the interval defined for Continue Delay. A continuous time scale can be built by a series of Continue Delay commands.

“Wait until time of day” delays start of the batch program until the time specified.

6.2.5.2 Record Macro

The function “Record Macro” converts your manually entered commands into batch file lines. Simply click “Record Macro”, perform experiment, and click “Record Macro” again.

6.2.5.3 Options

All items of the “Options” menu of the Batch window are related to the MONI-DA data acquisition system.

Check MONI-DA Compatibility

Some batch file commands cannot be executed by the MONI-DA. This command searches for such incompatibilities.

Upload to Device

Transfers a batch file to the MONI-DA memory.

Export

Export the current batch file as “WinControl-3 Compiled Batch File” (*.wccb). This file format is for future use. Upcoming MONI-DA versions will be enabled to directly download wccb files, that is, without being connected to WinControl-3. The final goal is to install batch files by remote control.

6.2.6 Settings Window

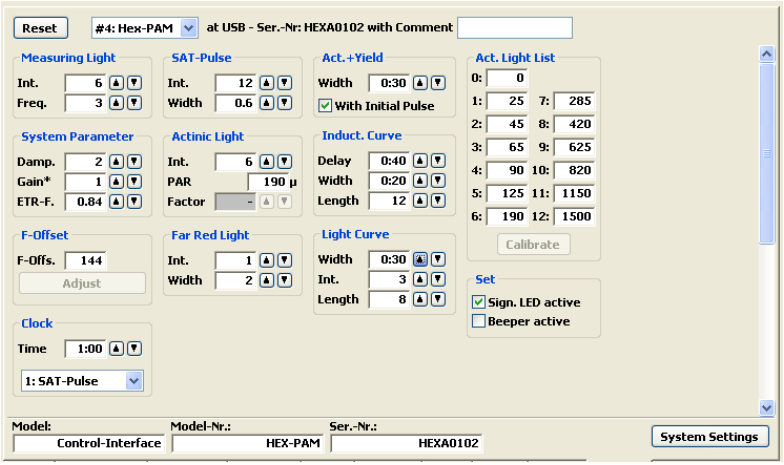


Fig. 30: Settings Window

Screenshot taken with predecessor model HEX-PAM.

The Settings window provides all options to configure instrument settings and the automated experimental routines Actinic + Yield, Induction Curve and Light Curve. These routines can be started manually by corresponding check boxes in the field “Program” on the bottom of all WinControl-3 windows. Also, they can be automatically triggered by the clock function.

Measuring light

Int. (intensity) and Freq. (frequency, see Table 11) adjustment. Frequency high (100 Hz) is active during saturation pulse analysis.

Table 11: Measuring Light Frequencies

Setting	Frequency, Hz
1	5
2	10
3	15
4	20
5	25
high	100

Damping

Damping is a software-based filter that specifically suppresses high frequency noise and, thus, can improve signal quality. Default setting for damping is 2 (two). Changing damping to higher values can make the MICRO-PAM response slow.

Gain

Gain corresponds to an electronic amplification factor. Settings 1 to 4 are available.

Adjust F-Offset

The command determines the background signal for subtraction from the total signal. Background signals must possess the modulation characteristics of measuring light to be recognized by a PAM fluorometer. These signals can arise from:

- Fluorescence from suspension media or detector filter excited by measuring light.
- Traces of modulated excitation light transmitted by the detector filter.
- Non-optical modulated "electronic noise".

Usually, the background signal increases with measuring light intensity and signal amplification (gain). Therefore, the Adjust command determines the background signal for all measuring light intensities and all gain settings. The currently active offset is displayed in the Moni-Bus Window with disconnected measuring heads.

Procedure

- Choose dim environment.
- Switch off any flickering light sources like fluorescent lamps or computer screens.
- Point fiber tip away from any objects, keep fiber tip clear.
- Run “Adjust F-Offset”

Clock Interval and Item

Adjust clock interval between 10 s and 60 min by adjusting the time interval (up/down keys) or enter numbers after double click. Choose clock item from drop down menu.

Clock items are saturation pulse analysis, Actinic + Yield, Induction Curve and Light Curve. A recovery experiment can be performed after induction and light curves (LC+Rec and LC+Rec).

SAT-Pulse

Adjust intensity (settings 1 to 12) and interval (width, 0.2 to 2.0 s) of saturation pulses.

Actinic Light

Adjust intensity of actinic light (settings 1 to 12). Values of the actinic light list are used.

Far Red Light

Does not apply for standard measuring heads of MICRO-PAM systems.

Actinic + Yield

The behavior of the Actinic + Yield program is defined by two factors: the duration (width) of actinic illumination (possible settings from 5 s to 5 min) and the option to start actinic illumination without preceding saturation pulse analysis (Initial pulse). The current actinic light intensity is used.

Induction Curve

Delay (range 5 s to 10 min) defines the dark interval between saturation pulse analysis with the dark-acclimated sample (F_0, F_M determinations) and beginning of actinic illumination.

Width (range 5 s to 10 min) is the time interval between two successive saturation pulse analyses in the light phase.

Length is the number of saturation pulse analyses carried out during actinic illumination. Thus, the duration of actinic illumination is “Length – 1” times Width

Light Curve

Width defines the interval between two successive saturation pulse analyses in the light phase. Intensity specifies the actinic intensity setting for the first light step (see “Act. Light List”). Length is the number of light steps which can range from 2 to 12. If length = 5 and intensity = 2, 5 light steps with intensity settings 2, 3, 4, 5, and 6 will be performed. The time required for a light curve results from Length times Width.

Calibrate

Calibration routine for actinic light. Requires measuring head with PAR sensor.

7 Saturation Pulse Analysis

7.1 Pulse-amplitude Modulated (PAM) Fluorescence

The PAM principle is illustrated by Fig. 31. The top part shows the total fluorescence of a sample. µs-measuring flashes are given throughout the experiment starting with “Pulse on”. These flashes cause spikes in the fluorescence trace. From left to right, an external effect induces a “False Signal” of continuous fluorescence in the darkened sample. Then the sample is exposed to a period of actinic illumination (“Actinic on” and “Actinic off”), and, finally, the sample is kept in the dark again.

During actinic illumination, an effect of stray light on the fluorescence signal is additionally assumed. The fluorescence level at onset of stray light plus actinic light is denoted “Actinic F_0“. The further increase of continuous fluorescence during illumination is denoted “Actinic F_V”, where the V stands for variable fluorescence. The “Actinic F_V“ reflects changes of the fluorescence yield in the sample because stray light and actinic light are constant during the illumination period.

In Fig. 31, not only continuous fluorescence varies but also the amplitude of fluorescence spikes. PAM fluorometers ignore the changes of continuous fluorescence and measure only the amplitude of fluorescence spikes. This is achieved by subtracting the fluorescence level just before the µs-measuring flash from the fluorescence level at the µs-measuring flash. In Fig. 31, the PAM fluorescence amplitude during the initial dark phase is denoted “Pulsed F_0”, and the maximum variable fluorescence at the end of actinic illumination is denoted “Pulsed F_V”.

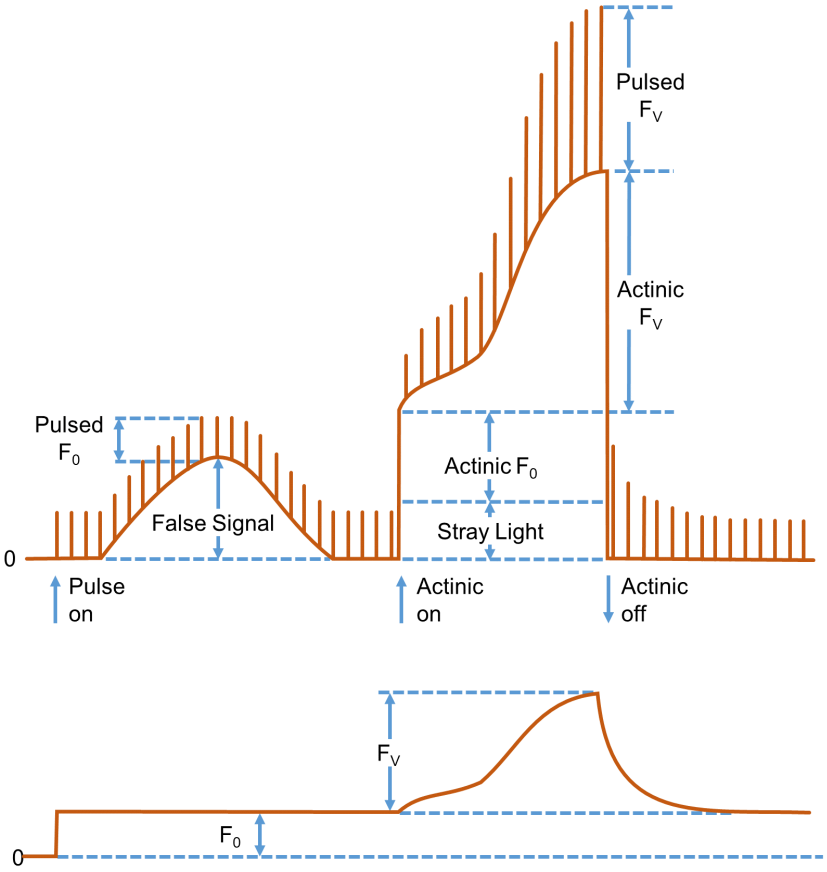


Fig. 31: Illustration of the PAM measurement principle

Figure redrawn for Dr. Ulrich Schreiber, Manual for PAM-101.

Because the µs-measuring flashes have constant amplitude, the varying amplitudes of fluorescence spikes is a measure of how efficient excitation light is converted into fluorescence. In other words, PAM fluorescence is proportional to the fluorescence yield.

The lower trace in Fig. 31 outlines the PAM fluorescence trace. Obviously, PAM fluorescence irons out the “False Signal” of total

fluorescence at the beginning of the experiment, and also the fluorescence jumps when actinic light is switched on and off. The course of continuous fluorescence within the range "Actinic F_V" resembles the corresponding trace of PAM fluorescence, because both measuring light and actinic illumination are constant.

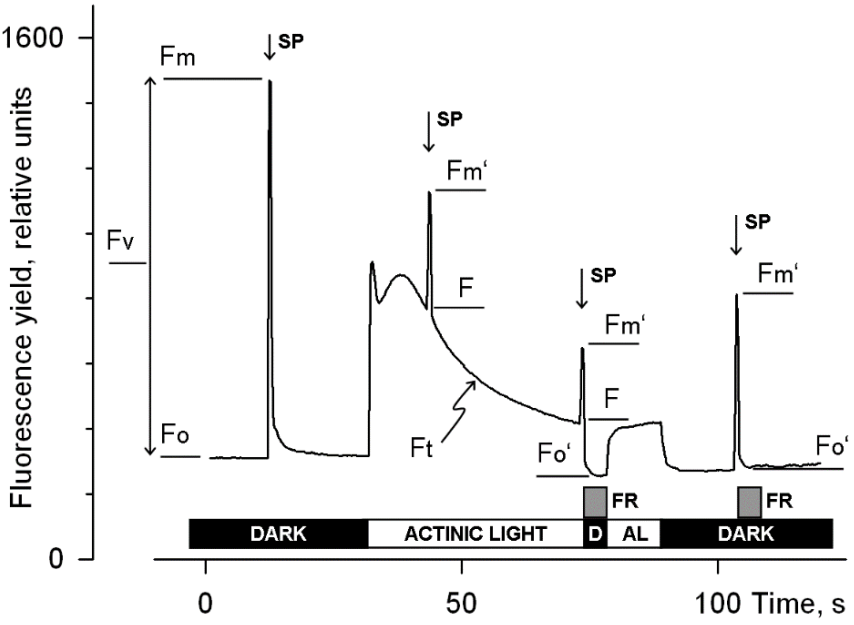


Fig. 32: Fluorescence Levels of Saturation Pulse Analysis

Y-axis (Fluorescence yield) corresponds to PAM fluorescence, see 7.1. AL, Actinic Light; D, dark; SP, Saturation Pulse; Ft, continuously recorded PAM fluorescence; FR, far red illumination.

7.2 Saturation Pulse Analysis

The five principal levels of PAM fluorescence which are used for saturation pulse analysis are shown in Fig. 32. Two of these levels (F_0 and F_M) must be measured with the dark-acclimated sample. The three other levels (F_0', F, and F_M') are measured with the actinic light-exposed sample or in a dark period following this light treatment. Some parameters of saturation pulse analysis require fluorescence measurement of the same sample in both the dark-acclimated and light-exposed state (Table 12, page 74).

Because PAM fluorescence is excited by µs pulses of constant amplitude, variations between fluorescence levels are usually interpreted as variation in chlorophyll fluorescence yield. This applies for variations between different types of fluorescence levels (e.g. between F_0 and F_M) and for variations of the same type of fluorescence level (e.g. the change of F_M' during a fluorescence induction curve).

Measurements with Dark-Acclimated Samples

F_0 Minimum fluorescence level excited by very low intensity of measuring light to keep photosystem II reaction centers open.

F_M Maximum fluorescence level elicited by a pulse of saturating light (Saturation Pulse) which closes all photosystem II reaction centers.

Measurements with Illuminated Samples

F_0' Minimum fluorescence level of illuminated sample. The F_0' is lowered relative to F_0 by non-photochemical quenching.

Under laboratory conditions, the F_0' level is determined during far red illumination in a dark interval following a saturation pulse. In this dark interval, far red light selectively drives photosystem I. As a consequence, electrons are removed from the intersystem electron transport chain and opening of photosystem II reaction centers is efficiently accelerated. As a result, photochemical quenching quickly becomes maximal as is the case for F_0 fluorescence. The non-photochemical quenching, which was built up in the light, dissipates slower and is noticeably as reduction of the initial F_0 to the F_0'. See Table 12 (page 74) for fluorescence quotients calculated with F_0'.

Under field conditions, natural light intensities drive photosystem II to a degree which renders far red action ineffective. Therefore, the MICRO-PAM and MONITORING-PAM measuring heads are not equipped with a far red light source. The F_0' is calculated according to Oxborough and Baker:

$$F_0' = \frac{1}{\frac{1}{F_0} - \frac{1}{F_M} + \frac{1}{F_M'}}$$

Oxborough K, Baker NR (1997) Resolving chlorophyll a fluorescence images of photosynthetic efficiency into photochemical and non-photochemical components - calculation of qP and Fv'/Fm' without measuring Fo'. Photosynth Res 54 135-142. https://doi.org/10.1023/A:1005936823310

In the Record table, the calculated value F_0' is preceded by a tilde sign (~).

F_M' Maximum fluorescence level of the illuminated sample. The F_M' is induced by a Saturation Pulse which temporarily closes all photosystem II reactions centers. F_M' is decreased relative to F_M by non-photochemical quenching.

F The F corresponds to the momentary fluorescence level (Ft) of an illuminated sample shortly before application of a Saturation Pulse.

To quantify photochemical use and non-photochemical losses of absorbed light energy, fluorescence ratio expressions have been derived which use two or more of the five relative fluorescence yields introduced above. Table 12 (page 74) compiles the fluorescence ratio parameters calculated by the Below, these parameters will be explained briefly.

F_V/F_M and Y(II) Maximum and effective photochemical quantum yields of photosystem II

The F_V/F_M and Y(II) estimate the fraction of absorbed quanta used for photosystem II photochemistry. F_V/F_M corresponds to the maximum photochemical yield of photosystem II, Y(II) is the effective photochemical yield of photosystem II. Measurements of F_V/F_M require that samples are acclimated to darkness or dim light so that all reactions centers are in the open state and non-photochemical dissipation of excitation energy is minimal.

In algae and cyanobacteria, however, the dark-acclimated state often is not showing maximal photosystem II quantum yield, as the photosystem II acceptor pool may be reduced in the dark by stromal reductants and, consequently, the so-called state 2 is formed exhibiting low photosystem II quantum yield. In this case, preillumination with moderate far red light should precede determinations of F_0 and F_M.

The Y(II) value estimates the photochemical use of excitation energy in the light. It is lowered with respect to F_V/F_M by partial closure of photosystem II centers and various types of non-photochemical energy losses induced by illumination.

q_P and q_L Coefficients of photochemical fluorescence quenching

Both parameters estimate the fraction of open photosystem II reaction centers. The q_P is based on the concept of separated photosystem II antenna units (puddle model), whereas the q_L assumes interconnected photosystem II antenna units (lake model) which was assumed to be present in leaves (*cf.* Kramer *et al.*, 2004). Determinations of q_P an q_L do not require fluorescence measurements with the dark-acclimated sample, except the F_0' mode is switched of and F_0' is calculated according to Oxborough and Baker (1997).

q_N and NPQ Parameters of non-photochemical quenching

Both parameters are associated with non-photochemical quenching of excitation energy, mainly involving a low thylakoid lumen pH- and a zeaxanthin-dependent quenching mechanism. The qN and the NPQ parameters require fluorescence measurements with the sample in the dark-acclimated and in the light-exposed states (cf. Table 12, page 74).

Calculation of NPQ (or SV_N; Gilmore and Yamamoto, 1991) corresponds to the Stern-Volmer equation for fluorescence quenching which predicts proportionality between fluorescence quenching (NPQ) and the concentration of fluorescence-quenching centers in the photosynthetic antennae (e.g. zeaxanthin).

Y(NO), Y(NPQ) and Y(II) Complementary photosystem II yields

Genty *et al.* (1996) and Kramer *et al*. 2004 have presented expressions describing the partitioning of absorbed excitation energy in photosystem II between three fundamental pathways the sum of which adds up to one:

Y(NO) non-regulated losses of excitation energy including heat dissipation and fluorescence emission,

Y(NPQ) regulated energy losses of excitation energy by heat dissipation involving ΔpH- and zeaxanthin-dependent mechanisms, and

Y(II) use of excitation energy for charge separation.

This concept of "complementary photosystem II quantum yields" is useful to analyze the partitioning of absorbed light energy in photosynthetic organisms. For instance, in the presence of strong light, a much higher Y(NPQ) than Y(NO) indicates that excess excitation energy is safely dissipated at the antenna level and that photosynthetic energy fluxes are well-regulated.

In variance, high values of Y(NO) would signify that excess excitation energy is reaching the reaction centers, resulting in strong reduction of photosystem II acceptors and photodamage, e.g. via formation of reactive oxygen species.

7.3 Relative Electron Transfer Rate (ETR)

Relative electron transfer rates for photosystem II are calculated according to:

$$\mathbf{ETR(II) = PAR \cdot ETR\text{-}Factor \cdot P_{PS2}/P_{PS1+2} \cdot Y(II).}$$

The basic idea of the ETR equation is to multiply Y(II), the effective photochemical quantum yield of photosystem II, by an estimate for the photon flux density absorbed by all photosystem II in the sample. The latter estimate is derived from three numbers:

(1) PAR Quantum flux density of photosynthetically active radiation (PAR) impinging on the sample.

(2) ETR-Factor Sample absorptance (= 1 – transmittance)

The ETR-Factor describes the fraction of incident photons absorbed by the sample. The most frequently used default value for

green leaves is 0.84 meaning that 84% of incoming light is absorbed. The ETR-Factor can be lower in bleached leaves or leaves containing considerable amounts of non-photosynthetic pigments like anthocyanins.

(3) P_{PS2}/P_{PS1+2} Relative distribution of absorbed PAR to photosystem II

The default P_{PS2}/P_{PS1+2} is 0.5 which assumes the photosystem II contributes 50% to total sample absorptance. The P_{PS2}/P_{PS1+2} may deviate from the idealized factor of 0.5 depending on wavelength of light and acclimation status of the sample.

7.4 Reviews on Saturation Pulse Analysis of Photosystem II

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Schreiber U (2004) Pulse-amplitude-modulation (PAM) fluorometry and saturation pulse method: an overview. In: Papageorgiou GC, Govindjee (eds) Chlorophyll *a* Fluorescence: A Signature of Photosynthesis. Springer, Dordrecht, pp 279-319. https://doi.org/10.1007/978-1-4020-3218-9_11

Table 12: Fluorescence Ratio Parameters

Source	Equation	Sample State	Range [Theory] [Experiment]
Maximum photochemical quantum yield of PS II (Kitajima and Butler, 1975)	$\frac{F_V}{F_M} = \frac{F_M - F_0}{F_M}$	Dark	[0, 1] [0, ~0.84]
Effective photochemical quantum yield of PS II (Genty *et al.*, 1989)	$Y(II) = \frac{F'_M - F}{F'_M}$	Light	[0, 1] [0,~ 0.84]
Quantum yield of light-induced (ΔpH- and zeaxanthin-dependent) non-photochemical fluorescence quenching (Genty *et al*. 1996, Kramer *et al*. 2004)*	$Y(NPQ) = \frac{F}{F'_M} - \frac{F}{F_M}$	Dark and Light	[0, 1] [0, ~ 0.9]
Quantum yield of non-regulated heat dissipation and fluorescence emission: this type of energy loss does not involve the action of a trans-thylakoid ΔpH and zeaxanthin (Genty *et al*. 1996, Kramer *et al*. 2004)*	$Y(NO) = \frac{F}{F_M}$	Dark and Light	[0, 1] [0, ~ 0.9]
Stern-Volmer type non-photochemical fluorescence quenching (Bilger and Björkman, 1990; Gilmore and Yamamoto, 1991))	$NPQ = \frac{F_M}{F'_M} - 1$	Dark and Light	[0, ∞] [0, ~4]
Coefficient of photochemical fluorescence quenching (Schreiber *et al.* 1986 as formulated by van Kooten and Snel, 1990)	$q_P = \frac{F'_M - F}{F'_M - F'_0}$	Light. If F_0' calculated, Dark and Light	[0, 1] [0, 1]
Coefficient of photochemical fluorescence quenching assuming interconnected PS II antennae (Kramer *et al.* 2004)	$q_L = q_P \cdot \frac{F'_0}{F}$	As $q_{P'}$.	[0, 1] [0, 1]
Coefficient of non-photochemical fluorescence quenching (Schreiber *et al.* 1986 as formulated by van Kooten and Snel, 1990)	$q_N = 1 - \frac{F'_M - F'_0}{F_M - F_0}$	Dark and Light	[0, 1] [0, ~0.95]

* Kramer *et al.* (2004) have derived more complex equations for Y(NO) and Y(NPQ). Klughammer and Schreiber (2008) have transformed the equations by Kramer *et al.* (2004) into the simple equations of Genty *et al.* (1996).

Table 13: References Cited in Table 12

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8 Specifications

Specifications are subject to change without notice.

8.1 ONLINE Configuration

8.1.1 Measuring Head MICRO-HEAD/3B

General Design

Housing: Polymer housing with optical block and fiber connector on one side, and a combined power line/RS485 socket on the opposite side

MICRO-HEAD/BK Leaf Clip: Consisting of 2 aluminum frames (3.5 x 2.5 cm), held together by magnet, 0.4 cm distance between sample plane of leaf clip and light guide, angle between sample plane and optical light guide: 60°

Cables: RS 485 data/power cable, 10 m standard length, connecting MICRO-HEAD/3B and MICRO IB4 PC Interface Box. RS 485 adapter cable, 0.6 m long, to connect MICRO-HEAD/3B to optional PC Interface Box MONI IB4/LAN or to optional MONI DA system for data acquisition

Flexible stand: Baseplate of acrylic glass 10 x 10 x 0.5 cm (L x W x H); flexible goose neck consisting of 20 links, 1.7 cm maximum diameter, 30 cm length, one end with metal thread equipped with 1 butterfly nut, 1 nut and 2 washers. Weight 114 g

Dimensions: Complete head with leaf clip, 13.5 x 3.5 x 4 cm (L x W x H)

Power consumption: Peak loads during saturating pulses 3 W. During measuring mode 0.15 W

Operating temperature: -15 to +40 °C

Weight: 96 g

Light Emission

Modulated fluorescence excitation: Blue power LED (typical peak wavelength 470 nm, full width at half maximum 22 nm). Photosynthetically active radiation (PAR) of measuring light at level of the sample clip range from 0.15 to 1.5 µmol m-2 s-1 at low modulation frequencies (5 to 25 Hz), and from 1.5 to 22.5 µmol m^{-2} s^{-1} at high modulation frequencies (100 Hz)

Actinic light: Same power LED as for modulated light. At sample level of leaf clip, 3000 µmol m^{-2} s^{-1} maximum PAR of actinic light, 8000 µmol m^{-2} s^{-1} maximum PAR of saturating flashes

Sensors

Fluorescence: PIN-photodiode protected by longpass filter (50% transmittance at 645 nm). Selective window amplifier to measure pulse amplitude modulated (PAM) fluorescence.

Photosynthetically active radiation (PAR): External LS-C sensor for selective PAR measurement, range 0 to 7000 µmol m-2 s-1, cosine-corrected for light incident at angles between -30° to +30° from the surface normal

Temperature: Thermocouple: Ni-CrNi, wire diameter 0.1 mm, -20 to +60 °C

Humidity: Capacitive-type humidity sensor on a specialized analog and digital integrated circuit, 0 - 100% relative humidity

8.1.2 Measuring Head MICRO-HEAD/3A

General Design

Modulated fluorescence excitation: Amber power LED (typical peak wavelength 598 nm, full width at half maximum 27 nm). Photosynthetically active radiation (PAR) of measuring light at level of the sample clip range from 0.15 to 1.5 µmol m^{-2} s^{-1} at low modulation frequencies (5 to 25 Hz), and from 1.5 to 22.5 µmol m^{-2} s^{-1} at high modulation frequencies (100 Hz)

Actinic light: Same power LED as for modulated light. At sample level of leaf clip, 3000 µmol m^{-2} s^{-1} maximum PAR of actinic light, 8000 µmol m^{-2} s^{-1} maximum PAR of saturating flashes

Further specifications: Same as Measuring Head MICRO-HEAD/3B

8.1.3 PC Interface Box MONI-IB4/LAN

Housing: Aluminum case with RS-232, USB-B, Ethernet, power supply sockets, and four M12 5-pole sockets for RS-485 communication

Interfacing: The interface box connects a computer with up to four MICRO-HEAD/3B (or one MONI-DA). RS-485 serial data communication is used between interface box and MICRO-HEAD/3B or MONI-DA. RS232, USB or Ethernet communication is used between interface box and computer

Recommended maximum cable lengths: To computer via USB and RS-232: 2 m. To computer via Ethernet, 100 m. To MICRO-HEAD/3B via RS-485: 10 m. To MONI-DA via RS-485, 100 m

Dimensions: 12 x 9.3 x 3 cm (L x W x H)

Weight: 400 g

Operating temperature: 0 to +40 °C

Power supply: Input: 100 to 240 V AC, 50 to 60 Hz. Output: 19 V DC, 3.7 A. Dimensions: 13.2 x 5.8 x 3 cm (L x W x H). Weight: 310 g

8.1.4 Fluorometer Software and Computer Minimum Requirements

Program: WinControl-3 System Control and Data Acquisition Program (Windows 10) for operation of the MICRO-PAM system, data acquisition and data analysis. Not compatible with Windows 10 on ARM

Saturation Pulse Analysis: WinControl-3 System Control and Data Acquisition Program (Windows 7, 8, 10) for operation of the MICRO-PAM system, data acquisition and data analysis

Program: Measured: F_t, F_0, F_M, F, F_0' (also calculated), F_M'. Calculated: F_0' (also measured), F_V/F_M and Y(II) (maximum and effective photochemical yield of PS II, respectively), q_L, q_P, q_N, NPQ, Y(NPQ), Y(NO) and ETR (electron transport rate). Fitting Routines: Two routines for determination of the cardinal points α, I_k and ETR_{max} of light curves

Further date acquired: PAR, leaf temperature, humidity

Additional feature: Automatic determination of signal offset for all light intensities and all gain levels

Communication Protocol: USB

Computer Requirements: Processor, 1 GHz. RAM, 512 MB. Screen resolution, 1024 x 600 pixels. Interface, USB 2.0/3.0

8.1.5 Flexible Ball Joint Mount for MICRO-PAM Measuring Head MICRO-HEAD/SG

Design: Two double-ball arm segments, two ball end pieces with photo thread (1/4” external), to mount a measuring head and a base plate with photo thread (1/4" internal), respectively.

Dimensions: 39 cm (L max.)

Weight: 410 g

8.1.6 Transport Box

Design: Aluminum box with custom foam packing for MICRO-PAM

Dimensions: 60 cm x 40 cm x 25 cm (L x W x H); 42 liter

Weight: 4.7 kg

8.2 STAND-ALONE Configuration

8.2.1 Measuring Head MICRO-HEAD/3B

As described in Section 8.1.1.

8.2.2 Measuring Head MICRO-HEAD/3A

As described in Section 8.1.2

8.2.3 Data Acquisition System MONI-DA

Housing: Robust water-proof cylinder consisting of a polyvinyl chloride (PVC) tube and poly-oxymethylene (POM) endplates. One endplate with 2 male M12 5-pole sockets connected in parallel (MONI-IB4/LAN communication, charging voltage), one male M12 5-pole socket for auxiliaries, and 7 female M12 5-pole sockets (MICRO-PAM, MONI-HEAD/485 communication)

Dimensions: Cylinder with diameter of 16 cm and length of 24 cm

Data management: Dual data storage on internal 8 MByte circular flash buffer and an industrial grade 512 MByte removable microSD flash card. Wireless data transfer via cellular phone or satellite modem. Online data transfer using RS-485 serial data communication.

Power consumption: 5 mW in standby mode. Operating mode, depends on the number of measuring heads connected

Battery: 12 V / 7.5 Ah (96 Wh) LiFePO4 battery.

Operating temperature: -30 to +60 °C

Weight: 5.4 kg

8.2.4 Flexible Ball Joint Mount for MICRO-PAM Measuring Head MICRO-HEAD/SG

As described in Section 8.1.5.

8.2.5 Transport Box

Design: Aluminum box with custom foam packing for MICRO-PAM including MONI-DA

Dimensions: 80 cm x 40 cm x 34 cm (L x W x H); 60 liter

Weight: 4.9 kg

8.2.6 Fluorometer Software and Computer Minimum Requirements

As described in Section 8.1.4.

8.2.7 PC Interface Box MONI-IB1

Housing: Aluminum case with USB-B socket, power supply socket, and M12 5-pole socket for RS-485 communication

Links: The interface box connects a computer with a MONI-DA using RS-485 serial data communication. The same line is used to charge the MONI-DA battery. USB communication is used between interface box and computer

Recommended maximum cable lengths: To computer via USB: 2 m. To MONI-DA via RS-485, 100 m

Dimensions: 9.7 x 6.3 x 3.5 cm (L x W x H)

Weight: 270 g

Operating temperature: 0 to +40 °C

8.2.8 Solar Panel MONI-SP

Design: Polycrystalline silicon panel. Highly resistant to water, abrasion, hail impact and other severe weather conditions. Equipped with a 4 m cable and plug for the AUX or INPUT socket of the Data Acquisition System MONI-DA. Several panels can be

connected in parallel to provide sufficient power under conditions of low insolation

Electrical characteristics: Vmax, 15.0 V, Imax, 0.63 A (at 1000 W/m2 sunlight). VOC, 19.6 V. ISC, 0.80 A

Dimensions: 50 x 35 cm (L x W)

Weight: 1.2 kg (incl. cable and plug)

8.2.9 Four-Way Distributor MICRO-HUB

Housing: Aluminum case with one M12 5-pole connector and four M8 5-pole connectors

Links: The interface box connects up to four MICRO-HEAD/3B Measuring Heads to one single MONI-BUS port of a MONI-DA data acquisition system

Recommended maximum cable lengths: 10 m between MICRO-HEAD/3B and MICRO-HUB, and between MICRO-HUB and MONI-DA

Dimensions: 10 x 6 x 3.5 cm (L x W x H)

Weight: 228 g

Operating temperature: -30 to +40 °C

8.2.10 Wi-Fi Modem MONI-DA/WIFI

Design: Weatherproof cylinder made of POM (Polyoxymethylene) containing a standard Wi-Fi modul. One endplate made of POM, the other endplate made of Plexiglas with 5-pole M12 plug connector. Including 10 m cable to connect the modem to the AUX port of the MONI-DA. Data transfer requires connection to a WLAN network or to a hotspot (2.4 GHz, 802.11 b/g/n)

Dimensions: 19.5 cm (L) 3.27 cm (Ø)

Weight: 140 g (modem), 320 g (cable)

8.2.11 Satellite Modem

Specifications depend on available electronic components at the time of order

9 Guarantee

All products supplied by the Heinz Walz GmbH, Germany, are warranted by Heinz Walz GmbH, Germany to be free from defects in material and workmanship for two (2) years from the shipping date (date on invoice).

9.1 Manufacturer's Guarantee

Under this Manufacturer's Guarantee ("Guarantee"), subject to the Conditions and Instructions below, Heinz Walz GmbH, Germany ("Manufacturer"), guarantees (§443 BGB) to the end customer and user ("Customer") that all products supplied by it shall substantially conform in material respects to the Specifications for 24 months from the delivery date (date on invoice). In this Guarantee, "Specifications" means the product's features (as may be amended by Manufacturer from time to time), which are set out under the headings "specifications" and/or "technical specifications" within the product's respective brochure, data sheet, or respective tab on the Manufacturer's website for such product, and which may be included with the documents for the product when delivered. In case of an eligible guarantee claim, this Guarantee entitles the Customer to repair or replacement, at the Manufacturer's option, and this Guarantee does not include any other rights or remedies.

9.2 Conditions

This Guarantee shall not apply to:

- Any defects or damage directly or indirectly caused by or resulting from the use of unauthorized replacement parts and/or service performed by unauthorized personnel.

- Any product supplied by the Heinz Walz GmbH, Germany which has been subjected to misuse, abuse, abnormal use, negligence, alteration or accident.

- Damage caused from improper packaging during shipment or any acts of God.

- Batteries, cables, calibrations, fiberoptics, fuses, gas filters, lamps (halogen, LED), thermocouples, and underwater cables.

- Defects that could reasonably have been detected upon inspection of the product when received by the Customer and not promptly noticed within ten (10) days to Heinz Walz GmbH.

- Submersible parts of the DIVING-PAM or the underwater version of the MONITORING-PAM have been tested to be watertight down to the maximum operating depth indicated in the respective manual. Guarantee shall not apply for diving depths exceeding the maximum operating depth. Further, guarantee shall not apply for damage resulting from improper operation of devices, in particular, the failure to properly seal ports or sockets.

9.3 Instructions

- To obtain guarantee service, please follow the instructions below:

- The Walz Service Information Form available at https://www.walz.com/support/repair_service.html must be completed and returned to Heinz Walz GmbH, Germany.

- The product must be returned to Heinz Walz GmbH, Germany, within 30 days after Heinz Walz GmbH, Germany has received

written notice of the defect. Postage, insurance, and/or shipping costs incurred in returning equipment for guarantee service are at customer expense. Duty and taxes are covered by Walz.

- All products being returned for guarantee service must be carefully packed and sent freight prepaid.

- Heinz Walz GmbH, Germany is not responsible or liable for missing components or damage to the unit caused by handling during shipping. All claims or damage should be directed to the shipping carrier.

9.4 Applicable law

- This Guarantee is governed by German law. Place of jurisdiction is Bamberg, Germany.

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