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User Guide for FASTtracka FAST REPETITION RATE FLUORIMETER HB179

HANDBOOK REFERENCE No:	**HB179**				
AMENDMENT RECORD:					
ISSUE:	**3.0**	**4.0**	**5.0**	**6.0**	**7.0**
DATE:	**13.09.97**	**23.07.97**	**08.09.97**	**23.09.98**	**09.01.03**
MOD NOTE:	**MN 982**	**MN 1027**	**MN 1035**	**MN1038**	**ECO0326/0337**
APPROVED:				**GPW**	**GPW**

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Chelsea Environmental Ltd
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1. INTRODUCTION

The FAST*tracka* Fluorimeter offers rapid, real-time, *in situ* measurements of photosynthetic characteristics of marine and freshwater phytoplankton. By exposing phytoplankton to a series of microsecond flashes of blue light at 200 kHz repetition rate, a saturation profile of PSII variable fluorescence is observed and recorded. Analysis of the observed fluorescence signal and knowledge of the excitation protocol allows calculations of the absorption cross section of PSII, the efficiency of photochemical conversion, and the rates of electron transport from PSII to PSI. The FRR Fluorimeter is designed to measure these parameters on dark adapted and ambient irradiated samples *in situ*.

Analysing the saturation profile of variable fluorescence induced by a sequence of fast repetition flashes allows evaluation of the following parameters:

Fo: background fluorescence yield when all reaction centres open
F: background fluorescence yield under ambient light
Fm: maximum fluorescence yield when all reaction centres closed
τ: time constants of electron transport from PSII to PSI (s)

Additionally, PAR is measured using an external irradiance sensor attached to the instrument. Including the measured photosynthetic parameters in appropriate models relating fluorescence and photosynthesis allows calculation of photochemical/nonphotochemical quenching, photochemical conversion efficiency, and primary production. Other incidental parameters are recorded by the instrument for monitoring performance and calibration, and include internal temperature, battery status, and error codes.

The FAST*tracka* may be deployed for profiling or for moored operations. In constant-duty profiling operations, the FAST*tracka* will continuously log up to 24 h of data at a 1 Hz acquisition rate when powered from the standard 15 Ah battery pack. In a moored operation, the acquisition lifetime may be extended to the timescale of months by reducing the flash repetition rate and properly managing the instrument sleep cycles. The FAST*tracka* may be powered externally through either the Interface or the Battery external bulkhead connectors, thus removing the limitation of the standard battery pack.

The FAST*tracka* is designed for maximum user flexibility. A comprehensive software package operates on an internal microcontroller and handles data collection, primary data reduction, and basic instrument functions. Data may be stored internally on a PCMCIA flashdisk, exported to a CTD or similar device over two 0-5 volt scaleable analogue channels, or transmitted serially over a host cable to a computer or terminal device. For most operations, flashdisk storage is recommended for simplicity and speed. Analogue interfacing is more complicated due to the differences between each manufacturer's CTD/logger specifications, and CI does not claim that the FAST*tracka* is compatible with all CTDs or loggers, especially older or custom models. However, our technical support team is ready to assist and advise users to interface the FAST*tracka* to any CTD or analogue logger. Since there is much variability in CTD performance, older models might require reconfiguration of the instrument analogue output channel or reconfiguration of the CTD itself. Please contact CI technical services for help with interfacing the FAST*tracka* with any other intelligent instrument.

The FAST*tracka* is shipped standard with a 15 Ah rechargeable battery pack, with an integral intelligent battery charging circuit which monitors battery temperature and charge characteristics. The internal charging circuit greatly simplifies the user's task of battery maintenance. Battery charge algorithms are computed internally with respect to charge state and temperature; the user is required only to provide adequate voltage and current at the charge plug. Proper charging capability is provided through the FAST*tracka* Deck Unit, but the customer is expected to ensure that the charging current and voltage to the battery pack does not exceed the specified limits for effective charging when using sources other than the Deck Unit to charge the battery pack. The battery lifetime and power consumption rates are heavily dependent on the flash rate and the excitation protocol intensities.

The FAST*tracka* is shipped with a Deck Unit, a deck unit interface cable, and a serial cable to allow RS232 communication between the FAST*tracka* and the user's computer or terminal emulator. The user is required to provide an adequate terminal emulation package (e.g. PCPlus) in order to communicate with the FAST*tracka*. In addition to allowing communication, the Deck Unit supplies power to the FAST*tracka* via an internal switch mode PSU. Consequently the instrument may be operated through the Deck Unit alone, without a battery pack. Finally, the Deck Unit contains a second internal switch mode PSU to properly charge the battery pack. Since this PSU is separate from the Host supply PSU, battery pack charging can occur simultaneously and independently of host operation.

The electronic systems of the FAST*tracka* include a Motorola MC68332 microcontroller operating at variable clock speeds up to 16MHz, a flexible FPGA digital logic system, and a nonvolatile PCMCIA flashdisk. The FAST*tracka* optical system utilises a proprietary high-speed/ fast repetition rate blue LED light source and a sensitive photomultiplier emission detector, both specially engineered for the excitation and observation of chlorophyll fluorescence.

Since the FAST*tracka* has been designed for maximal flexibility, each user's application may be as customised as is desired. Technical information is provided to help the user operate the FAST*tracka* with most standard deployment scenarios, but we realise that many items have been either customised or require additional information. Our technical services are ready to help you effectively use our instrument in any situation you require, in house or in the field.

2. INSTRUMENT RATINGS

2.1 PHYSICAL SPECIFICATIONS

Length:		635 mm	Instrument can + guard
		355 mm	Battery pack
		990 mm	Total mounted length
Diameter:		160 mm	
Weight:			
Without Battery pack	in Air:	~23kg	in Water: ~15kg
With Battery pack	in Air:	~39kg	in Water: ~24kg

Exterior Materials: Titanium, grade 2, or epoxy powder coated anodised aluminium
Annealed black Delrin
316 stainless steel

Pressure rating: 500m

2.2 ELECTRICAL SPECIFICATIONS

Power Consumption: 650 mA @1Hz FSRR @ 14V
300 µA @ sleep mode @ 14V

External Power voltage range:
Interface Connector: 18 - 72 VDC
Battery Connector: 13.5 - 18 VDC
CTD Operation: 10.5 - 18 VDC

2.3 PERFORMANCE

[Chl *a*] sensitivity: 0.1-30 $\mu g l^{-1}$

2.4 DATA COMMUNICATION

Standard:	RS422
Standard Serial Parameters:	9600 N 8 1
Flashcard Download:	9600 N 8 1 or 57600 N 8 1

3. OPERATING INSTRUCTIONS

Upon receiving your FAST*tracka* Instrument, follow these instructions to assure proper operation. Failure to follow these instructions may result in damage to the instrument and/or injury to the user.

3.1 UNPACKING AND ASSEMBLY

3.1.1 General Information:

Please note that the instruments are somewhat heavy, especially the battery pack. Be careful not to drop or jar the instrument by improper handling.

The FAST*tracka* is shipped in a high-impact case designed to protect the instrument from shock and vibration damage which often comes from handling during shipment. The instrument is shipped with the battery pack separate from the instrument can, with a protective guard surrounding the bulkhead connectors on the bottom. The battery pack may be attached prior to instrument operation, or the instrument may be operated directly through the Deck Unit.

3.1.2 Battery Operation:

The battery to FAST*tracka* cable may be attached either before or after mechanically connecting the two pressure cans. Attach the battery pack power lead to the correct bulkhead connector on the bottom of the instrument can, see diagram. Do not place undue strain on this cable, either as axial or bending loads. Undue strain will lead to premature failure of the connector. Premature failure may result in accidental shorting of the battery packs inside the can, or flooding of the battery pack. The pins and sockets of these connectors may be coated with Vaseline or other appropriate lubricant in order to ease mating.

WARNING: *Be especially careful when removing the cable from the battery pack. Removal of the cable from the battery pack end will expose the male leads of the bulkhead connector, which are at battery voltage and current. <u>Physical injury may occur if these exposed pins are accidentally shorted.</u> The cable may be removed for cleaning and greasing, but never leave the battery pack connector pins exposed where they might be accidentally shorted. Use a dummy connector or preferably keep the cable in place.*

To mechanically attach the FAST*tracka* can to the battery pack, first lubricate the mating surfaces with Dow 4, Parker O-ring Lube, or another appropriate lubricant. Similarly coat the mounting screws with a layer of lubricant. The mounting screws are either stainless steel or titanium and will not appreciably corrode, but lubrication increases the ease of removal after lengthy deployments. Mount the battery pack to the instrument can so that the battery cable is routed out of the way of the other bulkhead connectors. Affix the greased mounting screws firmly so there is no rocking or play between the cans. Rocking or play will chafe the mating surfaces and may accelerate corrosion.

3.1.3 Deck Unit Operation:

The Deck Unit will provide power to the FAST*tracka* only if mains power is supplied to the Deck Unit through the mains plug. If the FAST*tracka*
is requested to turn on without power being applied through the Deck Unit and if no battery pack power is available, the instrument will return an error code through the indicator LEDs in the optical head. If the battery cable is attached, and proper battery power is applied, and the host cable is incorrectly attached, the indicator LEDs will show proper wakeup codes, but no communication will appear on the RS232 cable. It is important to ensure that all cables are properly attached before operating the instrument.

With the Deck Unit cable attached to the FAST*tracka* interface bulkhead connector and proper mains power supplied to the Deck Unit, the FAST*tracka* should automatically operate.

3.2 ESTABLISHING CONTROL

With either the battery pack attached or the Deck Unit supplying power, the FAST*tracka* is ready to be turned on. The instrument will remain in SLEEP mode and may be awakened by:

a) toggling the magnet switch at the optical head
b) pre-setting wake up times through system software

When awakened, the instrument will begin to operate with the set up parameters last set through software control if autoacquire mode has been set, otherwise it will await further instruction from the operator. To establish communication with the instrument:

- connect the supplied 9 way serial cable between the Deck Unit and the host PC;
- connect Host Cable between the Deck Unit and instrument;
- correctly set the serial parameters on the terminal emulator which you are using. The instrument responds to 9600 baud, no parity, 8 data bits and one stop bit;

Use the magnet to turn on the instrument. The location of the magnet switch is located in the centre of the optical head.

When the FAST*tracka* recognises the wakeup request, the indicator LEDs will blink once, and the following menu will be displayed:

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This indicates that the instrument is up and running, and that the serial communication with the FAST*tracka* is correctly set. Continue with the instrument configuration as explained in the Software Reference section. The FAST*tracka* can be returned to sleep mode by using the magnet switch again, in which case the indicator LEDs will blink twice.

NOTE: *Improper operation and/or configuration of the terminal device, or terminal emulator running on the host PC, has often been the cause of many communication problems noted by users of this and other serial devices. Consult Appendix 2 for tips on serial communication to the FASTtracka before continuing if you have problems at this stage with establishing communication with the instrument.*

The indicator LEDs flash codes are used to inform the user of potential problems or instrument states without being required to attach a host computer or terminal. These codes include:

One long:	FAST*tracka*	on and ready to operate
One short:	FAST*tracka*	reset program
Two short:	FAST*tracka*	shutting down normally
Three short:	FAST*tracka*	refuses to turn on; no battery or Deck Unit power supplied
Four short:	FAST*tracka*	did not acknowledge shutdown request

A long pulse is roughly one second long, and a short pulse is roughly one half of a long pulse.

3.3 IMMERSION

- Before immersing the instrument, check the following:
- inspect the bulkhead connectors for looseness or improper seating;
- ensure cable ends are prepared using standard connector technique;
- that locking sleeves are fully locked;
- cables are fastened to the battery pack guard with cable ties or similar items using the holes provided;
- instrument cables are positioned so that there is a slight service loop in the cables;
- the bulkhead connectors will never be under any significant radial or axial strain;
- the battery pack is firmly mounted to the FAST*tracka* pressure can and the charging plug is tightly screwed in by hand;
- that external sensors, if connected, are securely fastened both mechanically and electrically and operational;
- that the sunblock is attached on channel A;
- all subsystems are functioning properly.

Inspect the mounting position of the instrument. For profiling operation, it should be vertical with respect to the water column, and it should not be shaded by any part of the mounting assembly. The ports for the dark chamber should be free and clear to channel the sample water as necessary, and the sunblock should be properly mounted on the optical head channel A. The instrument should be securely fastened to the mounting assembly, with a layer of neoprene or other cushion between the instrument and its mounting hardware. This cushion will help prevent dents and scratches in the exterior surface which might lead to premature corrosion. The instrument chassis ground is also in this instance not connected to any rosette or frame. As well, ensure that other cables, either electrical or mechanical, on the mounting frame, do not interfere with the optical head area of the FAST*tracka* .

Disconnect the host or battery charging cables if connected, and properly replace the correct charging plugs and dummy connectors. Check the o-ring seal on the charging plug for the battery pack for damage or neglect. Lubricate if necessary.

Use the magnet switch to initiate proper flashing. Observe the indicator LEDs signalling proper wakeup, and if the FAST*tracka* has been programmed to directly acquire, observe the excitation flashes.

When the instrument has returned to the deck, again use the magnet switch to shut off the FAST*tracka*. At this stage the battery pack may be charged or data may be downloaded, or the user may simply wish to let the instrument remain on standby until the next deployment. Please refer to the sections for Charging Requirements 3.11 and

Data Download 3.6.

Please note that the dark chamber ports, if attached, are delicate. Ensure that they are not struck or impacted during submersal. As well, although the instrument is equipped with auto PMT shutdown when exposed to high ambient light, it is recommended that the instrument is not operated under direct sun light.

3.4 REPETITIVE IMMERSALS/ DECK CONSIDERATIONS

Using the magnet switch removes the need to connect the host computer each time the instrument needs to be turned on or off. All setup parameters will remain at their previous settings. Thus, for profiling operations, the deck operator simply has to trigger the magnet switch and ensure that the instrument is either on or off as needed by waiting for the indicator LED codes to appear. Communication through the Deck Unit may as well be used to shut the FAST*tracka* off through software control.

It is important not to place undue strain on the cables and connectors attached to the FAST*tracka* instrument. As with any bulkhead connector or cabling used in oceanographic instruments, undue care in attaching and disconnecting cables will either damage the wiring or affect the sealing ability of the connector.

Battery charging and downloading data must still be performed periodically by attaching charging and host cables to the instrument. The design of the instrument allows charging and downloading to take place simultaneously and independently while the instrument is mounted to the lowering fixture as long as the cable access in the can guard is not obstructed. Please refer to the sections for Charging Requirements 3.11 and Data Download 3.6 for information on these topics.

3.5 HOST MODE

Host mode involves connecting a computer or other intelligent machine to the instrument in order to program, modify, or otherwise control the instrument. Host mode may be used for:

- downloading data from flashdisk storage;
- changing operational parameters;
- initiating a self calibration routine;
- real-time observation of instrument data (i.e. Desktop mode);
- instruction of instrument operation;
- demonstration of instrument performance;
- bench-top measurements;
- and service routines.

Host mode allows the user to power the instrument from the host cable when the instrument is disconnected from the battery can. The power management systems inside the instrument automatically choose between power sources. Host power may also be connected while the battery can is connected without damage.

In order to communicate effectively with the instrument, the user will need a computer with a terminal communications package. The protocol should be capable of trapping communication in order to effectively download data from the instrument. To simply reprogram or control the instrument, however, a dumb terminal is satisfactory. The instrument will communicate with terminals or emulators set for
9600 N 8 1.

Once the instrument and terminal are connected via the Deck Unit, and the instrument is activated via the magnet switch, the system supervisor will respond with a status message. If the instrument has just been turned on, the status will be:

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To cease Host Mode, shut down the instrument either through software or by using the magnet switch. If the battery is to remain attached, it is necessary to instruct the instrument to sleep by passing the magnet switch over the optical head, otherwise the instrument will remain on and drain the battery. Remove the host cable from the instrument and shut down the computer and external power supplies as required.

3.6 DATA DOWNLOAD

The collected data from the internal PCMCIA flashdisk may be downloaded at any time while the host cable is connected to the FAST*tracka*. The FAST*tracka* outputs data in BINARY format or ASCII format of file sizes up to 2 MB.

To download data, connect the host cable between the instrument and the host computer and ensure connection as described in Host Mode. Power the FAST*tracka* either through the host cable or by the battery pack as desired. Establish communication with the FAST*tracka* and proceed with data download as described in the Software Reference section 5.3.4.

Data download will stream information and data through the PC or terminal serial port. The user will need to provide appropriate terminal emulator software to maintain communication in the host computer, as well as XMODEM the data from the FAST*tracka*. Most reasonable commercial serial communications package should work with the instrument.

3.7 DARK CHAMBER & SUNBLOCK

The dark chamber and the sunblock are two pieces which must be affixed to the optical head to allow proper ambient and dark adapted measurements of FRR fluorescence data. The dark chamber is designed to retain sample water in dark conditions long enough for relaxation to occur in the phytoplankton sample. It is also designed to work identically in either a lowering or raising operation, and therefore the inflow/outflow ports are symmetrical. The sun block is designed to prevent ambient sunlight in the water column from degrading the quality of the fluorescence signal observed by the FAST*tracka* on the light chamber.

The dark chamber consists of a body and two ports and is fitted to Channel B, i.e. the optical channel without the indicator LEDs. The ports need to be screwed into the body before immersal, and must be oriented vertically 180° apart. If you are required to replace or remove the ports, do not use Teflon tape or other sealant on the threads of the ports. Such sealants are highly fluorescent and will contaminate the emission signal if exposed to the excitation flash. No sealant is required for attaching the ports to the dark chamber body.

The dark chamber internal body and the emission and excitation windows for channel B will need to be cleaned regularly using a non-abrasive brush, taking care not to scratch the Acrylic windows.

WARNING: *Be especially careful not to remove or loosen any of the retainer screws. These are properly torqued and set at the factory to hold the optical windows against the optical head. Removal or loosening of any of these screws will compromise the pressure integrity of the instrument and cause the instrument to flood*.

Similarly, the sunblock is mounted recessed (grooved) side facing the emission window, with the two plastic cheesehead screws fitting into the recesses on the window retainer, and an M4 screw affixing the sunblock to the retainer.

3.8 INSTRUMENT PACKING

Before packing, ensure that the instrument has been turned off in an appropriate fashion. Rinse the instrument and associated cabling with fresh water to remove salt deposits, especially in the optical head area. Salt deposits may form under the window retainers and damage the o-rings over time. A squirt bottle of fresh water is handy for rinsing the areas around and under the window retainers. Fully flush this area.

Vent the battery can by loosening the charging plug on the battery can bottom. Unmount the battery pack from the battery can guard and replace the mounting screws in their tapped holes. Remember to first disconnect the end of the battery cable which attaches to the battery can, otherwise “hot” leads will be exposed. Never leave the battery pack connector exposed in such a state.

Place the FAST*tracka* and battery can in the shipping case and ensure that the foam inserts are positioned correctly. Improper arrangement of the inserts might result in shifting or jarring of the instrument during shipment.

3.9 BENCHTOP OPERATION

Although the Instrument is primarily designed for vehicle use, profiling and short term moorings, the flexibility of the data interfaces and the host power mode allows the instrument to be used in a limited fashion as a bench top unit at sea. For extended use of the Instrument as such in a closed room, the battery can must be dismounted and the instrument must be operated off Deck Unit power.

WARNING: *Never operate the FASTtracka from the battery pack in a closed room. The battery pack, like all battery canisters, always presents a safety concern when charging and discharging in closed areas. For use as a benchtop unit, the instrument must always be operated in host mode with host power.*

- A benchtop configuration is set up as follows:
- secure instrument to desk, deck, bench-top or another solid surface;
- connect and secure host cables and computer.
- establish host mode communications and power (see Host Mode section of this Users' Guide).
- follow instructions in section 5. Software Reference .

3.10 POWER REQUIREMENTS

The FAST*tracka* is designed to draw its power from its own battery pack, thus removing the need for an external power source. A fully charged 15 Ah battery pack will last for 24 h of continuous flashing at 1 Hz flash rate.
The FAST*tracka* may be powered from the surface during host mode independent of the battery pack. In this arrangement, power is supplied on an umbilical cable along with communication and control signals. Operation in this fashion allows the instrument to be used from small craft independent of winch operation for as long as there is power supplied at the umbilical end. The FAST*tracka* requires 10.5 to 18 VDC supplied at the battery connector or 18 to 72 VDC at the Interface connector, rated at 1.0 amp maximum. The Host power supply at the surface must be set to always provide these parameters at the instrument.

The FAST*tracka* Deck Unit has two internal switchmode PSUs to

a) charge the battery pack and
b) power the instrument in Host Mode.

The Deck Unit may be supplied either with a UK standard mains plug or with bare wires for other nationality plugs. The input for the Deck Unit is 100-240VAC, 50-60Hz, 3A. If supplied with bare wires, the user must ensure that the appropriate mains plug is wired correctly. The three wires within the mains lead will be colored:

1. BROWN: Live
2. BLUE: Neutral
3. GREEN: Ground

3.11 CHARGING REQUIREMENTS

The standard battery pack houses three tiers of 7 Gates X cells, each cell of 5.0 Ah at 2 volts. The battery pack includes an intelligent battery charging circuit to monitor battery temperature and charge state.

Charging the battery pack may be done at any time while not deployed. Firstly, make sure the battery can is in a well ventilated area away from sources of spark and flame. Although the Gates cells are of damp electrolyte construction and are virtually immune to outgassing problems, it is always a good idea to ensure proper ventilation. The charge plug on the bottom of the battery can will provide proper venting when removed, using the CI supplied battery charge connector. Do not try to seal the recess of the battery can charging plug to the battery can (e.g. in order to protect it from salt spray). Ensure that while charging, that the charge plug area is kept free from spray or wash.

Gently remove the stainless steel charge plug on the bottom of the battery can by hand, taking care not to damage the o-ring or o-ring surfaces. Inside the 1-12 threaded hole may be seen the internal charging receptacle. Correctly align and connect the polarised battery charging cable from the Deck Unit, and secure the charging cable to something solid (e.g. with cable ties) to prevent an accidental tug on the cable from damaging the internal componentry of the battery can.

With the charging cable attached, supply power to the Deck Unit through the mains plug. Charging will automatically occur at the maximum recommended rate until power is removed or the battery charge connector is disconnected. The instrument is configured to automatically shut down if the battery voltage falls below 13.5 volts.

Battery voltage (charge status) can be read from the software in the System Setup menu. To accomplish this, have the battery pack connected to the instrument. Switch off the mains supply at the Deck Unit so that the charging ceases and battery pack takes over powering the instrument. After checking charge state in System Setup, the mains can be reconnected and charging can continue. Typical times to charge a standard battery pack using the Deck Unit:

- from 10% to 80% in 5 hours;
- from 10% to 95% in 24 hours.

Proper charging procedure will ensure safe and efficient maintenance of the rechargeable battery pack. The internal charging circuitry has over voltage and over current protection, but every effort should be made to ensure that the recommended limits to charging are not exceeded

3.12 OPTICAL REQUIREMENTS

3.12.1 Exterior Windows

The exterior optical windows are made of Acrylic, selected for its sheer strength and optical transmission characteristics. The FAST*tracka* should not be supported by or on its optical windows.

The windows may need to be cleaned from time to time. Use lint free tissue to remove most material, then clean the windows with impregnated optical paper. **DO NOT USE SOLVENTS** on the optical windows. The solvents will damage the windows & seep into the channels under the window retainers and degrade the o-rings there, leading to premature failure. Be sure that all fingerprints, oils, and other fluorescence sources are removed from the optical windows before instrument operation. Otherwise these substances will be a source of signal contamination. For that reason, soaps and detergents are not recommended for cleaning optical surfaces.

3.12.2 External PAR Sensor

The FAST*tracka* is supplied with a CI PAR sensor. For details on use and calibration data refer to the PAR sensor User Guide provided with the PAR sensor.

3.12.3 Photomultiplier Tube (PMT)

To allow fine scale measurement of the variable fluorescence at low chlorophyll concentrations (down to 0.1 μg/l) a PMT is used as a fluorescence detector. Care should be exercised to ensure that the PMT is not exposed to excessive light levels (e.g. direct sunlight shining into the emission windows). Exposing the PMT optics to direct sunlight will damage the photocathode at the very least temporarily, and perhaps irreparably given enough exposure. The FAST*tracka* incorporates an automatic shut down circuit to the PMT high voltage supply. When exposed to high ambient light, the sensor is switched off to prevent damage to the photocathode. A three second delay time is implemented before the PMT detector subsystem is repowered and checked.

Shining of bright lights into the emission windows to test instrument activity is strongly discouraged. Similarly, leaving the instrument on deck during a sunny day with the emission windows facing direct sunlight is also strongly discouraged. The sun block and the dark chamber are provided with the instrument. Attempting to operate the instrument without the sun block in place will at the least seriously compromise data integrity, and in the worst case allow damage to occur to the detector circuitry.

The FAST*tracka* will automatically check the PMT operation on power up with a self initiated internal calibration routine. The calibration check will indicate whether or not the PMT has suffered any permanent damage either due to damaging light or improper setting of the PMT gain in software. Should the check fail, the instrument will return a warning to the user indicating an uncalibrated PMT system. The self calibration should be performed with the optical head hooded from ambient light.

3.13 INSTRUMENT DATA OUTPUT

The FAST*tracka* FRR data may be output in two different but not exclusive manners. Two parameters (i.e. F_m and F_0) are calculated in real time using internal approximations. Using software settings, all data may be passed to the internal flashdisk for storage and later retrieval. In addition, the approximated F_m and F_0 values can be scaled to a 0 to 5V output and presented on separate analogue channels via the Analogue Output connector. See the Analogue Output section for further details.

The FAST*tracka* differs significantly from other active fluorimeters in the type of information which is gathered, processed, and presented to the user. The FAST*tracka* incorporates an integral 20 MB flashdisk (a solid state hard drive) to store data until a later offload, thus removing the need for customising or otherwise adapting non-compatible CTD systems. The inclusion of an intelligent data logger into the instrument design allows the instrument to be used much more flexibly than simply as a sensor.

In most instances, operation of the instrument as a self-logging unit is preferred over CTD interfacing in terms of overall information quality and ease of access.

To access stored data follow the instructions refered to in HOST MODE in this manual. The output data will be downloaded to a host computer as an XMODEM download, which will be written as a comma separated variable (CSV) file on the host PC. The CSV format is chosen as this is compatible with most standard spread sheet applications.

The following tables provide the format of data. The flash sequence data is transferred in blocks preceded by a header record. The header record contains several fields defining flash sequence and instruments parameters each separated by a comma.

Record format for sequence header

Field	Ref.	Format	Comments
Synchronising string		****	four asterisks
Sequence number	SN	NNNNN	1 to 99999
Channel Reference	CR	A (or B)	ambient or dark channel
Saturation flash width	SFW	NNN.N	saturation flashlet width in uS
Saturation flash count	SFC	NNN	number of integrated flashlets
Saturation interflash delay	SID	NNN.N	flash period in uS
Relaxation flash width	DFW	NNN.N	relaxation flashlet width in uS
Relaxation flash count	DFC	NNN	number of integrated flashlets
Relaxation interflash delay	DID	NNN.N	flash period in uS
Number of averages		NN	Number of flash sequences used per data point
Date		DD:MM:YY	
Time		HH:MM:SS	
PMT HV	HV	NNN	up to 3 digit number
PAR		NNNNN	up to 5 digit number
Pressure		NNNNN	up to 5 digit number
Temperature (future use)		±NN.NN	i °C - IPTS68 range -2 to 35
Conductivity (future use)		NN	mScm^{1} 0 to 70
Supply voltage		NN.NN	main DC-DC converter output in V
Supply Current		NNN	supply current in mA
Instrument Temp.		NN.N	
Error Code		H	one byte HEX
PMT reference	PCAL	NNNNN	
Acquisition mode		NN	
Autoranging Stored Value		NN	
Autoranging Upper Limit		NN	
Autoranging Lower Limit		NN	
Valid data (Autoranging)		NN	

Record format for saturation and relaxation data

Field	Format	Comments
Flash count	NNN	
Integrated reference	NNNNNN	size depends on the number of integrated sample
Integrated Signal	NNNNNN	size depends on the number of integrated sample

Flash count will increase from 1 to SFC for saturation zone and 1 to DFC for relaxation zone. If the instrument is configured to deliver only saturation flashes, then no relaxation flashes will be output.

After collecting the raw data necessary to calculate FRRF parameters, the FAST*tracka* presents the user with a series of numbers corresponding to the integrated (per flash) excitation and emission signal for both the saturation and relaxation sequences. These numbers represent the integrated signal, for each flash in the flash sequence, seen by the reference photodiode and the photomultiplier detector, respectively. Internally, the FAST*tracka* performs a quick approximation on these integrated data series in order to provide the user with some realtime estimate of F_m and F_0 , in case these values are required for the analogue output channel. In order to make this approximation, the FAST*tracka* first ratios the emission data against the excitation data, giving a series of numbers (length = SFC + DFC) representing fluorescence yield (i.e. the ratio of fluorescence out per excitation light in). This series of fluorescence yield is used to approximate F_m and F_0 using the following:

F_m = the average of the final 10 saturation flash Em/Ex ratios

F_0 = the average of the first two saturation flash Em/Ex ratios

3.14 ANALOGUE OUTPUT

The FAST*tracka* can be software configured to present an analogue voltage representing the internally approximated F_m and F_0 on the Auxilliary bulkhead connector. The pin configuration for the bulkhead connector and all other connectors may be found in the appendix.

In order to accommodate the large dynamic range of the FAST*tracka* , the analogue voltage is normalised, i.e. the output voltage seen on the bulkhead connector is a normalised representation of the digital value scaled against a value configured by the user via software. After each acquisition, the FAST*tracka* sends the approximated F_m and F_0 data digitally to an internal DAC, which creates the resulting analogue signal given the pre-programmed scale factor. This signal is buffered and held on the analogue output pins to await polling by the external analogue monitoring system.

An example: For the hardware full scale range of 5 volts, if the pre-set F_m scale is configured as 2.0, and the approximated F_m is calculated to be 1.4, then the output observed on the F_m analogue pin will be:

V_{out} = (F_m / scale) * full scale = (1.4 / 2.0) * 5 volts = 3.5 volts

If for some reason the approximated F_m and F_0 data exceeds the scale value, the analogue output will limit to 5 volts with no damage to the internal circuitry. As well, if the internal approximation returns a spurious value of F_m and $F_0 < 0$, the analogue output will swing to 0 volts.

3.15 CTD OPERATION

The FAST*tracka* can be used with a Seabird 911 CTD.

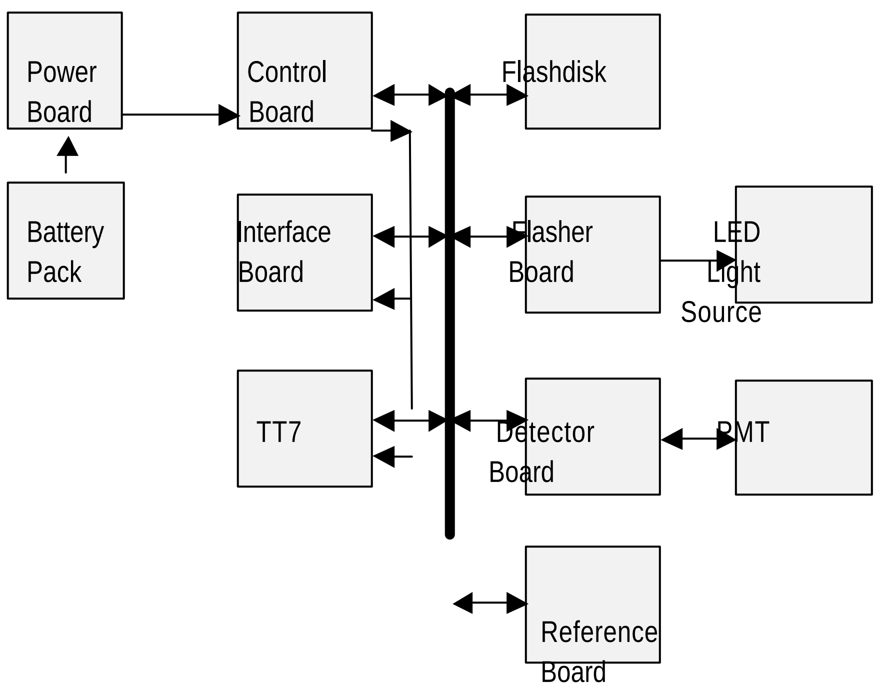
The analogue signals F0 & Fm can be connected for data logging and power can also be provided from the CTD, providing the CTD can provide the necessary 650mA. The Battery connector is used to accept the power input and the CTD_sens line on the connector needs to be linked to positive power, to enable working voltages down to 10.5V. In CTD operation mode the FAST*tracka* will switch on as soon as power is applied. Connection details showing CTD operation and the Pressure Sensor option are shown in section 6 and Appendix 1.

4. TECHNICAL REFERENCE

Due to the complexity of the instrument circuitry and optics, service of the FAST*tracka*, involving removal or inspection of the internal components, should be attempted only by CI trained technical support staff. There are no user serviceable components inside the instrument. Any attempt to open the instrument or battery assembly and service any of the componentry will void the warranty.

This notwithstanding, a short technical description of the FAST*tracka* and its subsystems has been provided to inform the user of the internal operation of the instrument. This description is designed to be functional in nature, and many details will be omitted in order to provide only the information which is pertinent to the instrument operation.

A block diagram of the FAST*tracka* is pictured below:



The operation of the FAST*tracka* is supervised by a controller system built around a MC68332 based datalogger, a TattleTale Model 7 (Onset Computer Corporation, Pocasset MA USA). The datalogger resides on a controller board, which services tha datalogger and provides a supervisory control circuit. Nonvolatile mass storage is provided by a PCMCIA flashdisk, and nonvolatile system parameters are stored in a Dallas NVRAM. The Dallas NVRAM also provides clock functions for system wakeup and long term deployment programming.

An interface board controls FRRF protocols while simultaneously monitoring a PMT detection and amplification system. The interface board is also responsible for monitoring auxiliary sensors such as the add-on temperature and pressure probes, as well as the standard CI external PAR sensor. A power management board provides automatic power switching between battery operation and externally supplied power, preferentially protecting the battery pack while external power is available.

4.1 CONTROL BOARD

The control board is designed around a Tattletale Model 7 datalogger from Onset Corporation (Pocasset MA, USA) and a PCMCIA Flashdisk (M-Systems, Santa Ana CA, USA). The automatic data protection, absence of moving parts and the low power consumption of a flashdisk makes this solution applicable for mooring applications, where vibration and power saving concerns are critical.

The main datalogger is controlled by a supervisory circuit to achieve maximum power management. Toggling the magnet switch or pre-programmed operations will place the instrument into wake-up state. Further communication from the Interface connector through a RS-422 transceiver on the power board allows protocols stored in NVRAM to be modified or deleted. The instrument operating program is burned into the datalogger flash ROM during FRRF assembly at CI and is set to auto-launch whenever the power supervisor circuit dictates.

The datalogger has a variable speed digital clock, which is set according to the tasks executed by the instrument. During periods of numerical computation, the clock speed is increased to 16 MHz to efficiently process and reduce the raw fluorescence data. At other times the microcontroller clock is automatically reduced to 32 kHz to minimise power consumption. The controller board has shutdown control over the remaining subsystems, maintaining the proper duty cycle for further minimisation of power consumption.

4.2 INTERFACE BOARD

The interface board executes the FRRF protocols, provides interface to the auxiliary sensors and handles A/D and D/A conversions. It is based around an Atmel 6005 field programmable gate array (FPGA) which emulates the logic circuitry for generating FRRF flash protocols, and twin 10 bit flash AD converters. The FPGA implements all the glue logic, generates timing for FRR protocols, data acquisition and conversion, and interfaces between the controller board and the external PAR sensor.

4.3 FLASHER BOARD

The flasher board is responsible for triggering the LED light sources at 200kHz repetition rates. For each optical channel there are six chains of LEDs connected in parallel, with each chain of 14 LEDs connected in series. The entire flash board assembly is mounted in a shielded enclosure to minimise electronic noise.

An optical rod position in the centre of each lamp assembly provides a reference signal proportional to the flash intensity. This signal is measured on the Reference board simultaneously to the fluorescence emission. This excitation light data is presented to the user as REFERENCE data.

WARNING: Never look directly into the LED light source of the FAST*tracka*. Although the LED sources, unlike flashlamp sources, do not emit appreciable amounts of UV, the LEDs are focussed into a small sample volume and the intensity is correspondingly high. Damage to the eyes may occur if the beam is viewed directly.

4.4 DETECTOR BOARD

A Hamamatsu R928 side-on photomultiplier tube (PMT) is used to detect the fluorescence from phytoplankton exposed to excitation light. The emission light, after passing the entrance of the optical windows and aperture, is directed by a series of prisms to a passive collimator. After collimation, the emission light is filtered by a CI custom specified fluorescence band pass interference filters (Corion Coporation, Holliston MA, USA), and then passes through 12mm of Schott RG-665. After filtering, the emission light is focused onto the PMT photocathode.

The PMT gain is controlled by a programmable PMT high voltage supply. Varying the HV on a PMT will consequently vary the overall PMT gain characteristics, and the FAST*tracka* controls its gain in a series of steps, each step being a factor of four greater than the previous. After amplification, the PMT signal and the reference excitation signal described above are sent to the interface board for digitisation, manipulation and storage.

An onboard PMT calibration system provides a history of PMT performance over time. Periodically, a small and known amount of red light is leaked to the PMT from an onboard stable LED. The observed PMT signal is compared to a factory determined pre-set level, and differences between the present and the pre-set level indicate the amount of PMT wear.

4.5 POWER BOARD

The instrument takes power from its own battery pack or from the Interface connector, or from power on the Battery connector. The Battery input is 13.5 -18 VDC, unless the CTD detect line is enabled, which allows voltages down to 10.5 VDC. Host power is 18 - 72 VDC.

4.6 BATTERY PACK

The battery can contains three tiers of 7 Gates X cells, each at 2V nominal and 5Ah. A vented charging connector is accessed through a charging plug in the bottom of the can. Power output is provided through a bulkhead connector and waterproof pigtail in the top of the can. An intelligent battery charging circuit is designed into the battery can to automate the charging cycle.

4.7 PAR SENSOR

The FAST*tracka* is fitted with a bulkhead connector and external connecting cable which mate directly to a Chelsea Instruments PAR Irradiance Sensor, which is shipped standard with the instrument. The PAR sensor is powered by the FAST*tracka* , and the PAR signal is returned to the FAST*tracka* for measurement. The FAST*tracka* outputs PAR readings in the range 0 to 4095. This corresponds to an analogue input range of 0 to 4095 mV. The light intensity can then be calculated from this value using the formula supplied on the PAR sensor calibration sheet.

4.8 PRESSURE SENSOR OPTION

The FAST*tracka* is fitted with a bulkhead Auxilliary connector for connection of the Chelsea Instruments Pressure Sensor option. The Pressure sensor is powered by the FAST*tracka* , and the pressure signal is returned to the FAST*tracka* for measurement. The FAST*tracka* outputs pressure readings in the range 0 to 4095. This corresponds to an analogue input range of 0 to 4095 mV. The pressure can then be calculated from this value using the formula supplied on the Pressure Sensor calibration sheet.

5. SOFTWARE REFERENCE

5.1 SOFTWARE OVERVIEW:

The FAST*tracka* system software is embedded in the instrument and is executed whenever the instrument is turned on. Main Menu looks as follows, with five options:

```
=====================
   Main Menu
 =====================
   1. Run
   2. File
   3. System Status & Setup
   4.  Error and PMT Log
   X. Shut Down
```

Run menu covers all functions pertaining to acquiring data, File menu covers all functions pertaining to data storage on the flashcard, and System Setup covers all functions pertaining to instrument configuration and setup. Error and PMT Log allows the user to view history information if desired. Shut Down instructs the instrument to power down into deep sleep mode.

5.2 SYSTEM PARAMETERS & STRUCTURES:

The FAST*tracka* has initial values of certain items which must be accessed at start-up and properly set in order for the instrument to function properly. This is termed the instrument configuration, and most parameters are set in the System Setup menu. Other parameters, such as software versions and flashcard volume, are not user configurable, and are either set into the code at the factory, or are determined by hardware.

In generating the light sequences which stimulate fluorescence and in acquiring fluorescence data, the FAST*tracka* requires information on variables pertaining to the format of the flash sequence and the manner in which data acquisition is handled. The structure of this information is called a Protocol. A “safe” default protocol (protocol #10) is hard-coded into the instrument and may be recalled at any time. Up to 10 user defined protocols may be stored in memory and recalled by their number (i.e. 0-9). The location of each of these protocols is termed a “slot”. One slot needs to be selected as the “boot protocol”, so that the instrument, when powered, has reasonable values in the protocol area from which to generate a flash sequence if desired. The user thus, by programming different protocols, can select the type of protocol the instrument will wake up to. In addition to defining the type of stimulating flash sequence to be executed, the protocol also dictates detector gain and the manner of data handling (e.g. flashcard storage, analogue output, and so on).

Data collected by the FAST*tracka* may be stored on an internal flashcard in a format called a “file”. These files may be erased, viewed or downloaded through the file menu. If the protocol dictates storage to flashcard, before the acquisition begins the user is prompted for a filename. This filename is stored with the file data in the instrument and can be used to annotate each file.

When the instrument is set to autoacquire mode, the FAST*tracka* will automatically generate a filename with a format corresponding to the acquisition date and time.

5.3 FAST*TRACKA* SYSTEM MENUS

5.3.1 System Setup Menu

System Setup has 14 options and displays the present setup parameters:

```
=====================
   System Setup
=====================

Fast Repetition Rate Fluorometer -  Ver 1.0
FPGA Version -  Ver 0.1
Instrument ID - Ser
Flashcard Size -  20 MB
AutoAcquire is DISABLED

Tue June 10 10:36:48 1997
Controller Battery Voltage = 14.88 V
Controller Current        = 0.090 A
Electronics Temp          = 22.91 Deg C

A:    Set Date and Time
B:    Boot protocol slot number -     0
C:    AutoAcquire is DISABLED
D:    REF Amplifier offset (counts)-  128
E:    PMT Amplifier offset (counts)-  120
F:    Reserved
G:    Reserved
H:    F0 analog output scale maximum - 1.00000
I:    FM analog output scale maximum - 1.00000
J:    PMT calibration threshold is -  200 counts
K:    Ref calibration threshold is -  200 counts
L:    Set PMT gain constants
M:    Check PMT calibration
X:    Reset to Safe values
Select option or '0' to return:
```

SYSTEM SETUP Header:

```
Fast Repetition Rate Fluorometer -  Ver 1.0
FPGA Version -  Ver 0.1
Instrument ID - Ser
Flashcard Size -  20 MB
AutoAcquire is DISABLED
```

Tue June 4 10:35:50 1997
Controller Battery Voltage = 14.88 V
Controller Current = 0.096 A
Electronics Temp = 22.95 Deg C

The header presents the basic instrument configuration either as programmed at the factory or programmed by the user. These are organised as follows:

- Software version (factory set)
- FPGA configuration version (factory set)
- instrument serial number (factory set)
- Internal flashcard size in MB (autoset)
- status of AutoAcquire (user set)

- Date on internal clock (user set)
- Voltage on controller battery (autoread)
- Current consumption of instrument (autoread)
- Temperature of instrument internally (autoread)

Menu Options:

A. Set Date and Time: Use this menu to change the instrument's clock. Enter in the format of MM/DD/YY HH:MM:SS then press return.
B. Boot protocol slot number: This field allows the user to change the boot protocol which is loaded into active protocol upon startup. Acceptable ranges are from 0-10. Protocol slot 10 contains hard-coded safe values.
C. AutoAcquire: Enable autoacquire if you desire the FAST*tracka* to begin acquisition upon wakeup. This parameter is automatically activated when the instrument is set to acquire in programmed acquisition mode, immediately before it is set to sleep. As well, the user must set this parameter to instruct the instrument to automatically acquire data on wakeup by magnet switch.
D. REF Amplifier offset (counts)- This value is used to maximise the dynamic range of the reference channel. It is preset at the factory around 128. It may range from 0-255 and corresponds to a voltage offset used by the instrument in establishing signal background level. It should not be tampered with by the user.
E. PMT Amplifier offset (counts)- 120 This value is used to maximise the dynamic range of the fluorescence channel. It is preset at the factory around 125. It may range from 0-255 and corresponds to a voltage offset used by the instrument in establishing signal background level. It should not be tampered with by the user.
F. Reserved.
G. Reserved.
H. F0 analogue output maximum scale - This value sets the scale factor for normalising the Fo value produced in the onboard reduction. The user chooses this to roughly match the Fo values expected. The user should refer to the Analogue Output section of this manual.
I. FM analogue output maximum scale - This value sets the scale factor for normalising the Fo value produced in the onboard reduction. The user chooses this to roughly

match the Fo values expected. The user should refer to the Analogue Output section of this manual for more information.

J. PMT calibration threshold is - This value sets the threshold under which the PMT calibration routine is not allowed to fail. This value is set at the factory and should not be changed by the user unless instructed to do so by CI Technical support.

K. Ref calibration threshold is - This value sets the threshold under which the reference signal is set not to fail. This value is set at the factory and should not be changed by the user unless instructed to do so by CI Technical support.

L. Set PMT Gain constants: These instrument units are set at the factory to accurately program the fluorescence detector gain.

M. Check PMT Calibration: Choosing this option runs an automatic check of the PMT calibration and sends this information to the PMT Calibration Log. The optical head needs to be in the dark under a hood for this test to be properly performed, otherwise the test may return unreasonable values.

X. Reset Configuration: This option clears all configuration information and restores “safe” values into configuration.

5.3.2 Error and PMT Log Menu

The Error and PMT Log menu is used to monitor system errors and the state of the PMT fluorescence detector calibration. For each of these two logs, either the log may be viewed or cleared in total. The log menu looks as follows:

```
=====================
   Log Menu
 =====================
   A. Print Error Log
   B. Clear Error Log
   C. Print PMT Calibration History
   D. Clear PMT Calibration History

   Press 0 to return
```

The Error Log returns time stamped errors along with their enumerated explanation. The Calibration History stores information pertaining to the recent PMT response characteristics. Both of these Logs are more used for troubleshooting than day to day operation.

5.3.3 System Shutdown

Selecting this option generates a user prompt to confirm shutdown. Using this option will not enable Programmed Acquire (see Programmed Acquire Menu) but will place instrument in an ultra-low deep sleep mode. Power may be disconnected at this stage without any damage.

5.3.4 File Menu

File Menu is used to monitor and control file storage, retrieval and deletion operations on the internal flashcard. It has 6 options:

=====================
File Functions
=====================
1. Directory
2. Offload files Xmodem to host PC
3. Reserved
4. Format Flashdisk
5. Display file
6. Offload Data Dump
0. Return

1. Directory: Choosing this selection will display to the user a list of files all presently stored on the flashcard. Each file will be assigned a number according to its sequence on the card, and file data like name, date, size and location will as well be presented. Any key may be pressed to stop the Directory during display.
2. Offload File: Choosing this menu option allows users to download data from the flashcard to a host PC attached to the Host Connector through the Deck Unit. Firstly, the Directory will be displayed and a File Number will be requested for download. After a number has been chosen, the user is prompted to choose the transfer rate for the file if the user opts for a fast download i.e. a baud rate of 57600, the user must change the baud rate of the communications application. Next, the user can choose between a binary or ASCII file download. For ASCII files the instrument decompresses the internal binary data into an ASCII text file which it stores on an internal 2MB ram. This process is indicated by a series of dots which scroll across the terminal screen. After this process, the user is notified to start an XMODEM transfer, and a 30 second time-out is begun. In this time the user should begin the appropriate download procedure from their own host PC. Data is not removed from the card at this stage.
3. Resrved
4. Format Flashcard: This menu option provides an entire flashcard erase and reformat. It is mostly used as a service option. Note:- Individual files cannot be deleted.
5. Display File: Choosing this option allows the user to look at file information as stored on the flashcard. It is mostly used for diagnostics to see that a file has been properly recorded.
6. Offload Data Dump: This option allows the user to offload data from the flashcard between user defined address boundaries, ignoring any file names.

5.3.5 Run Menu

Run Menu has 5 options and displays the active protocol:

=====================
Run Menu
=====================
1. Discrete Acquire
2. Programmed Acquire
3. View/Edit Current Protocol
4. Save Protocol

5. Restore Protocol

to Return

*** Boot Protocol = 0 ***

6.	0	Acquisitions
7.	1	Flash sequences per acquisition
8.	100	Saturation flashes per sequence
9.	4	Saturation flash duration (in instrument units)
A.	0	Saturation interflash delay (in instrument units)
B.	ENABLED	Decay flashes
C.	20	Decay flashes per sequence
D.	4	Decay flash duration (in instrument units)
E.	61	Decay interflash delay (in instrument units)
F.	1000	ms Sleep-time between acquisitions
G.	0	PMT Gain in Normal mode
H.	DISABLED	Analogue Output
I.	DISABLED	Desktop (verbose) Mode
J.	ACTIVE	Light Chamber (A)
K.	INACTIVE	Dark Chamber (B)
L.	DISABLED	Logging mode to internal flashcard
M.	90	Upper Limit Autoranging Threshold value
N.	15	Lower Limit Autoranging Threshold value

Description of options:

1. Discrete Acquire: Selecting this option will execute data acquisition according to the protocol parameters set in the active protocol. The active protocol is displayed each time Run Menu is selected. When selected, this option prompts the user as follows: If “Logging mode to internal flashcard” is DISABLED, pressing return will execute data acquisition. If ENABLED, pressing return will prompt the user for a filename for identification purposes. At that point, pressing return will execute data acquisition according to the active protocol.
2. Programmed Acquire: This option calls a sub-menu for programming the FAST*tracka* for long term operation. Refer to the Programmed Acquire section 5.3.6.
3. View/Edit Current Protocol: Selecting this option allows the user access to menu options 6-L. Refer to the Edit Protocol section 5.3.7.
4. Save Protocol: This option allows the user to store the active protocol in one of the user configurable slots for future use. Selecting this option will prompt the user for a slot number, which may be from 0 to 9. Pressing return will write this protocol to the appropriate slot. Saving a protocol will overwrite any protocol presently stored in the selected slot.
5. Restore Protocol: This option allows the user to replace the active protocol with one previously stored in one of the user configurable slots. Selecting 0-9 will retrieve the protocol from the chosen slot, even if that slot has invalid or potentially damaging protocol values. Selecting 10 will retrieve a “safe” protocol which can be used as a template to modify and save future protocols.

5.3.6 Programmed Acquire Menu

Programmed Acquire Menu is a sub-menu of Run Menu, and is used to generate wakeup tables which the FAST*tracka* reads to acquire data over long timescales. By correctly programming wakeup tables and setting the Programmed Acquire option in motion, the FAST*tracka* will set itself to sleep for a predetermined time, wake up when the time is correct, execute a predetermined protocol, and go back to sleep until the next appropriate wakeup time. Used in this way, the instrument can stretch its operational lifetime on a single battery into several months by spending the interim time a sleep instead of idling.

Programmed Acquire uses a table of wakeup times which are sequentially programmed into an alarm clock which, while system power is off, monitors and compares the present time to the preset wakeup time, and issues a wakeup call when the two times match. The table may be constructed by the user either by programming in a series of discrete times, dates and protocols, or automatically by selecting a start time, a sleep period, a number of wakeups, and a protocol.

If a user forces a wakeup and is manually running the FAST*tracka* when a wakeup is scheduled, that wakeup time will be missed but still retained in the wakeup table. If the table is not further modified, at the next request to sleep the FAST*tracka* will purge the table of any missed wakeups and proceed with the next programmed future wakeup.

To take the FAST*tracka* out of Programmed Acquire mode necessitates holding down the 0 key on the terminal whilst forcing a wakeup with the magnet, until the Main Menu is observed. If a power glitch occurs the FAST*tracka* may exit out of the program into the TT7 prompt, this will require the user to type RUN and press the enter key.

Programmed Acquire Menu has 6 options:

```
 =======================
   Programmed Acquire Mode Menu
 =======================
   1. Print Schedule Table
   2. Edit/Set Discrete Wakeup Dates/Times
   3. Set Regular Wakeup Dates/Times
   4. Delete Entire Wakeup Table
   5. Delete a Schedule Entry
   6. Send FRRF to sleep for future wakeup

   0. to Return
```

Programmed Acquire Options:

1. Print Schedule Table: Selecting this option displays the current wakeup table. The user is shown a list of currently programmed wakeup dates, times and protocols.
2. Edit/Set Discrete Wakeup Dates/Times: Selecting this option allows the user to program into the instrument discrete wakeup times. Entries which are added are automatically sorted in chronological order.

3. Set Regular Wakeup Dates/Times: Selecting this option prompts the user for an initial wakeup time, giving a default value of 1 minute in the future. Next the user is prompted for a inter-sequence delay in minutes, the default being 5. Then the user is prompted for a total number of wakeups to perform, the default being 100. Finally the user is prompted for the protocol to be used for these acquisitions, the default being 10. The user must ensure that there is a valid protocol in the slot being requested.
4. Delete Entire Wakeup Table: This option deletes the entire wakeup table. The user is prompted for confirmation before the table is erased. Any response but a "y" or "Y" will abort the erase.
5. Delete a Schedule Entry: Selecting this option allows the user to selectively delete any one entry from the wakeup table.
6. Send FRRF to sleep for future wakeup: Selecting this option prepares the instrument to sleep and sets the AutoAcquire configuration bit. The user is prompted for a "y" or "Y" to continue; any other response returns the user to the previous level. Sleep then commences until the next programmed wakeup, when acquisition commences.

5.3.7 Edit Protocol Menu

The active protocol is the set of parameters by which the FAST*tracka* determines the manner in which FRR fluorescence information is generated and processed. The event of collecting fluorescence data, internally analysing it to produce integrated flash sequences, and outputting the data as per the user's specification is called an acquisition. An acquisition may be made up of one or more flash sequences, and each flash sequence is made up of a series, generally 120, of high speed flashes.

The default protocol will generate a flash sequence comprising 100 saturation flashes, each one microsecond in duration and spaced one microsecond apart, followed immediately by a series of 20 relaxation, or decay, flashes, each one microsecond in duration and 50 microseconds apart.

At least one flash sequence must be executed in order to generate the raw data required by the FAST*tracka* for FRRF analysis. Flash sequences may be averaged internally in order to reduce noise effects on very low concentrations, e.g. up to 16 flash sequences may be internally averaged before the averaged flash sequence data is passed to storage or analysed for output.

The Edit Protocol selection is used to prevent accidentally erasing or modifying the active protocol. The user is required to select this option before being given access to the active protocol options 6-L. Once "3" has been selected from the Run Menu, the user is prompted for a selection 6-L:

1. Acquisitions: This protocol field sets the number of acquisitions to be executed. This will correspond to the number of datasets stored on the flashcard, if flashcard storage is selected. A maximum of 20887 acquisitions can be stored on a 20MB flashcard.
2. Sequences per Acquisition: This field corresponds to the number of flash sequences which the FAST*tracka* will average before passing the integrated flash array on for internal analysis and data storage. This field may range from 1-16. Averaging more than 16 samples can be performed on a spreadsheet.

3. Saturation Flashes per sequence (SFC): This is the number of saturation flashes in the flash sequence. It can range from 1-100.
4. Saturation Flash duration (SFW): This field is a machine code for the duration of each saturation flash, and can range from 4 to 100. It is important to keep this parameter less than half of the flash period. See the next section for further details.

A. Saturation interflash delay (SID): This field is a machine code for the time between the beginning of each saturation flash, and can range from 0 to 65535. See the next section for further details.
B. Decay Flashes ENABLED/DISABLED: Use this field to disable Decay flashes. Setting this option to DISABLE will cause the FAST*tracka* to skip the decay flash generation during a flash sequence.
C. Decay flashes per sequence (DFC): This field is the number of decay flashes in the flash sequence, and may range from 1 to 20. A flash sequence may have no decay flashes; this must be programmed by DISABLING the Decay Flashes, in option B above.
D. Decay flash duration (DFW): This field is a machine code for the duration of each decay flash, similar to the saturation flashes, and can range from 4 to 100. See the next section for further details.
E. Decay interflash delay (DID): This field is a machine code for the time between decay flashes, similar to the saturation interflash delay, and can range from 0 to 1000. See the next section for further details.
F. Sleep-time between sequences: This field sets the time delay between the end of the previous acquisition and the start of the next. Only short times may be entered here (in milliseconds), from 100 to 60000 (1 minute). Longer sleep-times should be programmed with the Programmed Acquire Menu.
G. PMT gain in Normal mode: There are two modes of data acquisition, the default Normal mode and Auto Ranging mode. When choosing this option the user is prompted to: Press Y for Auto Ranging Mode, N for Normal mode. If Y is chosen the user is prompted to: Enter a value for the lower signal Limit 0-9 (3 is the default). The lower signal limit is a value where the signal from the flourescence detector can be considered as noise. If N is chosen the user sets the gain level of the fluorescence detector channel. It is graded in steps of four, i.e. x1, x4, x16, x64, x256. A setting of x0 sets the photomultiplier gain to zero.
H. Analogue Output: Enabling this mode instructs the FAST*tracka* to present the scaled Fo and Fm approximate values to the analogue output bulkhead connector. See the Analogue Output section of this Manual for further details.
I. Desktop Mode: Enabling this mode will spool the collected acquisition record to the screen in real time. This information may be collected by a screen capture utility or simply viewed.
J. Light Chamber: Enabling this option will activate optical channel A during acquisition and allow it to flash.
K. Dark Chamber: Enabling this option will activate optical channel B during acquisition and allow it to flash. If both channel A and B are enabled, an acquisition will alternate channels starting with channel A. Also, an acquisition comprises only one channel. Thus, for an acquisition setting of 1, with both channels enabled, only channel A will flash. Requesting 4 acquisitions will flash ABAB, etc. See the section on Protocol Examples, below, for more information.

L. Logging mode to internal flashcard: Selecting this option will instruct the FAST*tracka* to store all measured and calculated data to the internal flashcard for later retrieval. When this option is selected and the instrument is not operated in AutoAcquire mode, the user is prompted for a filename after selecting number of acquisitions, but immediately before acquisition begins. When this option is selected and the instrument is operated in AutoAcquire mode, the FAST*tracka* creates a filename automatically of the format SDYHHMMSS (sequential day of the year, 24hr, 59 minute, 59 seconds).
M. The Upper Limit Threshold value ranges from 55-99. This value is used when in Auto Ranging acquisition mode. For a current PMT gain of e.g. 16, a percentage is calculated from your current running average and the running average max, if this value is greater than the upperlimit threshold the PMT gain is automatically switched down in gain to a PMT gain of 4.
N. The Lower Limit Threshold value ranges from 5-45. This value is used when in Auto Ranging acquisition mode. For a current PMT gain of e.g. 16, a percentage is calculated from your current running average and the running average max, if this value is less than the lowerlimit threshold the PMT gain is automatically switched up in gain to a PMT gain of 64.

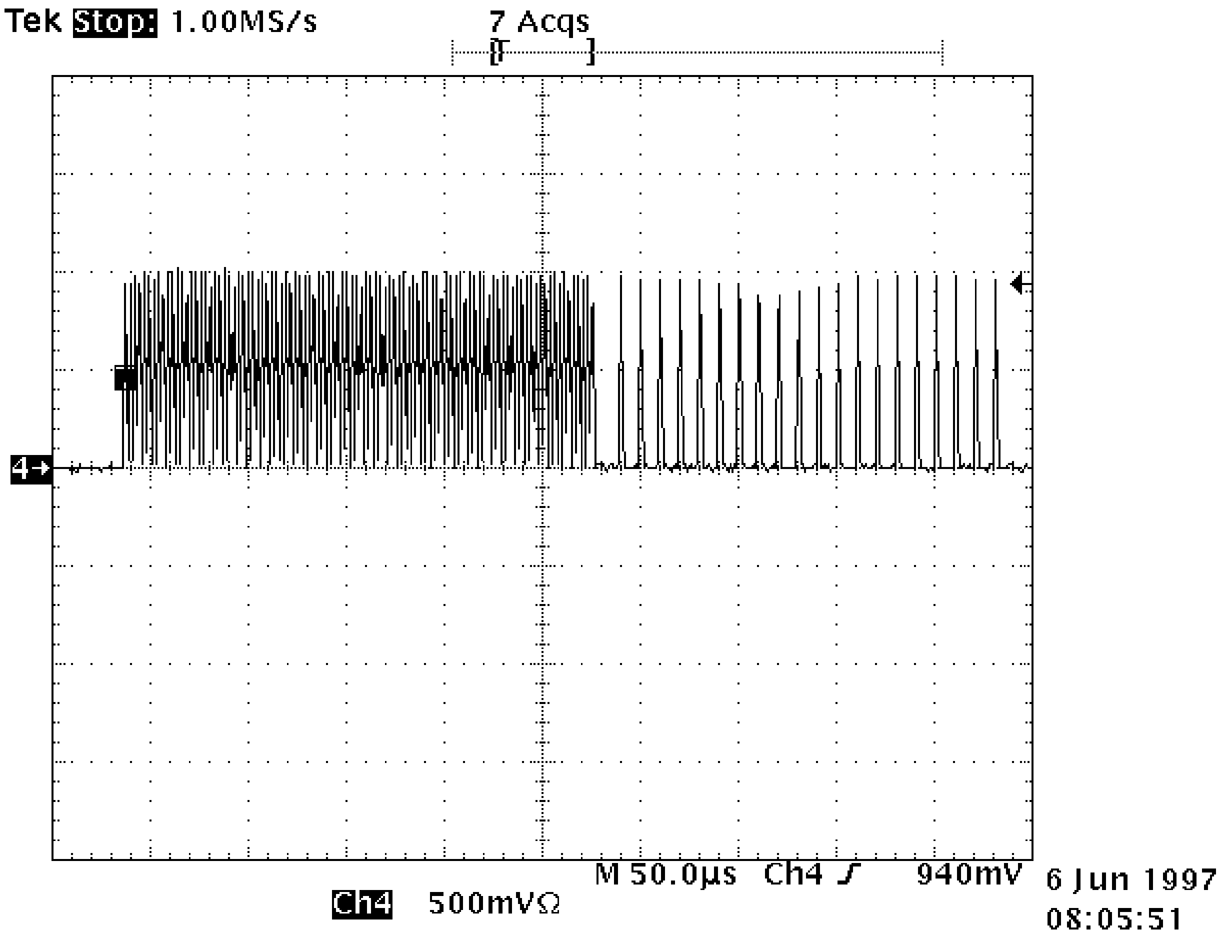
5.3.8 Protocol Examples

The following sequences should aid the user in understanding the different acquisition actions taken when different acquisition options are selected in the protocol.

The column on the left gives the pertinent aspects of an acquisition. The fields noted are number of acquisitions (option 6), sequences per acquisition (option 7), enable channel A (option J), and enable channel B (option K). The column on the right shows the resulting flash sequences in the order generated, as well as the symbol “d”, which indicates when an acquisition is complete, and the data is presented either to flashcard or analogue output.

Acquisition Options: Flash Sequence Result:

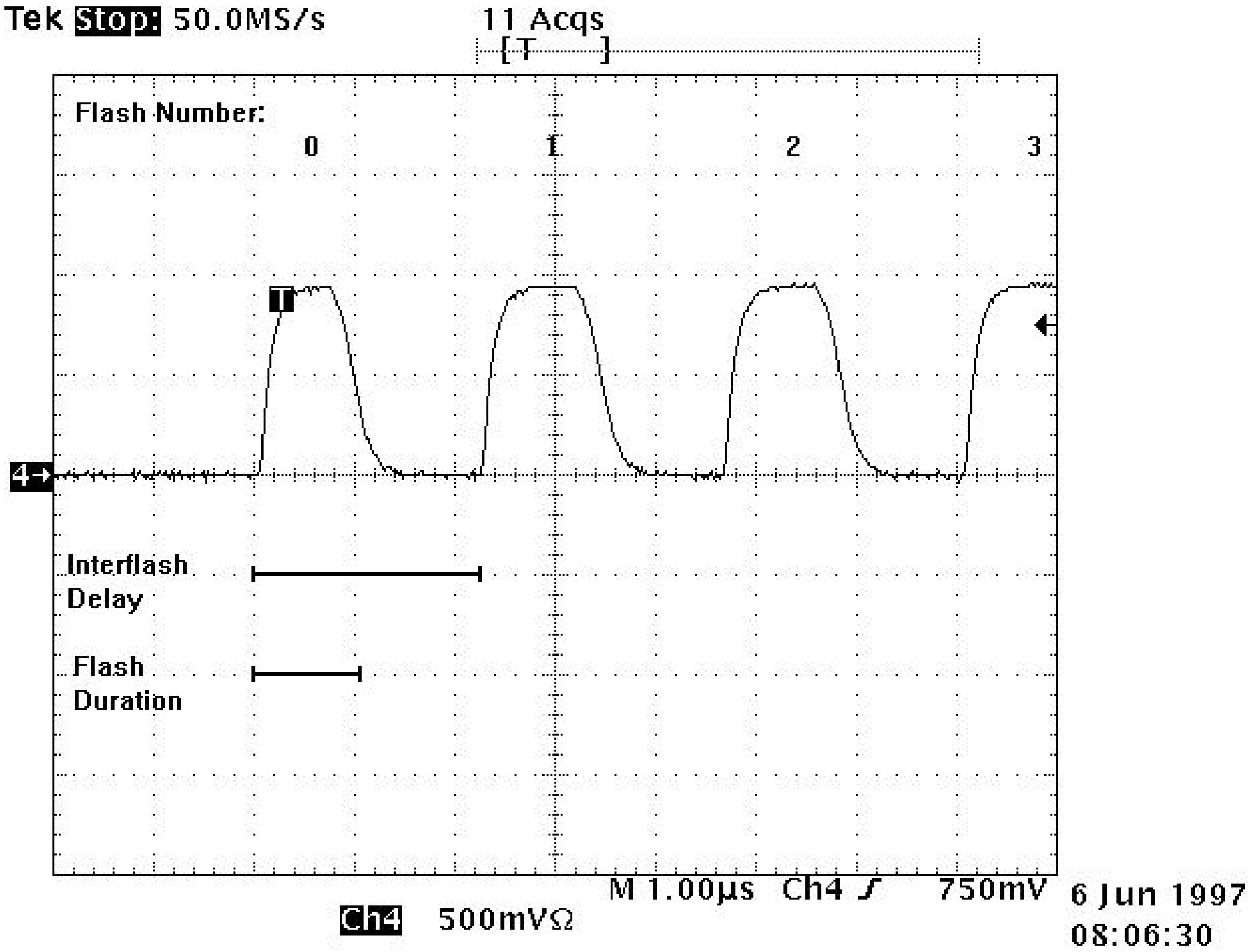
5,1,Yes, No...AdAdAdAdAd
5,1,Yes,Yes...AdBdAdBdAd
5,2,Yes,No..AAdAAdAAdAAdAAd
2,2,Yes,Yes...AAdBBd



This above figure illustrates the actual timing of a flash sequence consisting of 100 saturation flashes and 20 relaxation flashes. The entire operation, as pictured, requires only 450 µs for the programmed protocol. The Saturation group should be contained within a 250 µs frame, and the relaxation group may be stretched into the order of milliseconds if desired. The above protocol was generated with the following parameters:

SFW = 4
SFC = 100
SID = 0
DFW = 4
DFC = 20
DID = 12

Although the above picture shows all the flashes compressed into an overall window of 500µs, this protocol would be impractical for measuring actual samples. A more reasonable protocol would set DFP to 61, giving 50µs delays between decay flashes.



The flash duration (options 9 and D) is programmed in instrument units corresponding to clock cycles in the FPGA, as integers ranging from 4 to 100. The minimum value is set to 4 which gives a flash duration of 1.1µs, this being above 1 µs, which is the design specification for the detector electronics. Each additional integer increases in the flash duration value will increase the flash duration time by 60 ns.
Therefore period = (1.1 + (x - 4) * 0.06) µs.

The interflash delay (options A and E) is programmed in instrument units corresponding to a software clock separating the request for each flash. When an individual flash is generated, the FAST*tracka* programs the FPGA hardware counter to deliver a flash of width described by the flash duration value, then it enters a software loop to await the start of the next flash. The range of programmable values are from 0 (no wait; just overhead time) to 1000. An input value of 0 corresponds to a delay of 2.8 µs and integer increases in interflash delay will increase the flash period in steps of 800 ns.
The time between the last saturation flash and the first decay flash is the sum of the saturation interflash delay and decay interflash delay. Subsequent delay flashes are then separated by the programmed decay interflash delay time.

5.4 INTERNAL DATA HANDLING AND ANALYSIS

The FAST*tracka* uses a high speed FPGA logic circuit to read video-speed A/D converters which monitor the observed signal from both the photomultiplier fluorescence detector and photodiode excitation detector. These signals are digitised every 125 nanoseconds during a flash sequence, and this discrete information is stored sequentially on video speed SRAM as a linear array of 10-bit datapoints covering the entire flash sequence duration.

After the flash sequence is completed, the FAST*tracka* microcontroller reads the discrete data from the SRAM and parses it into a series of numbers corresponding to the integrated signal (either fluorescence or excitation) for the 0-nn saturation + decay flashes. Each digitised datapoint is of 10 bit range (i.e. 0 to 1023), and thus an integrated flash often will give values ranging around 3000 to 4000, as a microsecond flash can be sampled roughly 8 times at 125 nanosecond clocking.

Consequently, for a one microsecond flash (saturation flashlet duration = 4), an integrated number which exceeds 8000 should be considered spurious. If a PMT signal under such a protocol exceeds 8000, then each digitised signal must be close or equal to 1024, which is the upper limit of the 10 bit converter (the FAST*tracka* 10 bit converters represent a 0-4 volt signal as a digitised value ranging from 0- 1023). In this case, the PMT gain should be reduced in the protocol. It is preferred to have the PMT (emission) signal high enough to use the most dynamic range of the instrument, but not too high so that in some cases clipping occurs.

5.5 SOFTWARE MODIFICATIONS, V0.1 TO V1.0.0

The changes noted here serve to inform the user as to which changes have been implemented in both system software and hardware for the FAST*tracka* instrument for which this manual is designed.

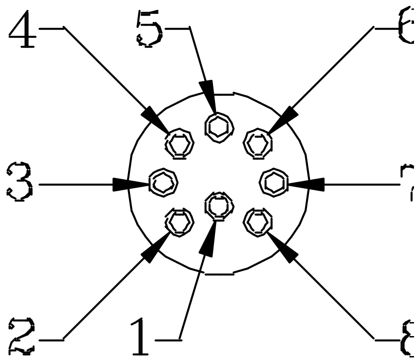
1. Magnet Switch Operation: The system hardware and software has been modified to accept a magnet switch instruction to issue a wakeup request and begin autoacquire. PL 6500-A issue instruments (running V0.1 software) precluded AutoAcquire mode from being executed on magnet switch wakeup, and could only be executed by attaching the Host cable.
2. Intelligent Shutdown: Magnet switch requests for shutdown in PL 6500-B hardware (running V0.2 software) first are relayed to the main microprocessor. Within a 10 second window, the main processor may complete its present task and signal proper shutdown before being switched by the PIC system controller. PL 6500-A hardware (running V0.1 software) implemented direct shutdown and did not allow task completion.
3. Battery Monitor: PL 6500-B hardware (running V0.1 software) did not allow the user to monitor the charge state of the battery pack, if attached. PL 6500-B hardware (running V0.2 software) allows the user to actively monitor the battery voltage level in real time through the System Setup menu when the instrument is powered by battery only. The System Voltage field has been replaced with Battery Voltage.
4. Wakeup Dates & Times: V0.2 software allows the user to selectively delete programmed wakeup dates and times in Programmed Acquire menu.
5. Internal Clock: V0.1 software has an error in setting the internal clock properly in certain circumstances.
6. System History Information: V0.2 software improved system functioning by implementing system history tables, Main Menu option 4. When errors occur, they are passed to an error handler which stores a time-stamped error code in NVRAM for later inspection.

7. Configuration Information: V0.2 software protected certain system parameters which were unnecessarily available to V0.1 users, including Serial Number and some calibration fields.
8. Shutdown Request: V0.2 software allows Main Menu option "X" to request an immediate instrument shutdown directly from software.
9. Configuration Options: V0.2 software removes the access to certain configuration parameters, and includes an option to check PMT calibration discretely.
10. Run Options: V1.0.0 software allows the user to acquire data in two modes Auto ranging and Normal. In Auto ranging mode the instrument starts with a gain setting of 16, an algorithm decides which PMT gain setting to use given the best readings. The algorithm used is Running Average = 0.9 * Running Average + 0.1 * PMTmax. If after 10 iterations of the algorithm, on a particular gain setting the running average is below the lower threshold limit value e.g. 15%, then the gain will automatically increase to the next higher gain. If the running average is above the upper threshold limit value of 90%, the gain will automatically decrease to the next lower gain. The 100% number is based on the flash duration, with a number of 8000 binary for each 1.1µs. The flash duration period in µs is calculated from the instrument units by the following equation: Flash Duration = 1.1 + (X - 4) * 0.06) µs, where X is the flash duration in instrument units. The running average max is calculated by using the following equation: Running Average Max. = (Flash Duration / 1.1) * 8000. The Inter Flash Delay has to be at least twice the Flash Duration. Therefore, in auto ranging mode and normal mode if the user enters a value for Flash Duration that is greater than half the Inter Flash delay, a suitable value for the Inter Flash duration is calculated.
11. Adaptive Storage: The FastTracka has no way of knowing whether or not it is storing useful data. The adaptive storage is an extension of the auto ranging. The idea is that, if there is no meaningful data, instead of storing this to the flashcard, a null record is stored. The definition of no meaningful data would be a signal lower than the user entered lower signal limit on a gain range of 256.
12. Fast Download: The FastTracka can now download files to the PC at a baud rate of 57600 in binary or ASCII. This is achieved using an Xmodem protocol, the user must set their terminal emulation application to accept files downloaded using the Xmodem protocol for ASCII or binary files.
13. Flashcard Improvements: The FRRF file delete facility no longer corrupts the file storage on the flashcard. There is a flashcard dump facility which will dump the whole contents or part of the contents of the flashcard if required.
14. Pressure Sensor: The software has been modified to accept an input from a pressure sensor.
15. Intel Flashcard Driver: The software now works with Intel and M-Systems flash cards, and the file tables are stored on the flashcard not in NVRAM.
16. 8Hz Acquisition: Using 10 mS sleep time between acquisitions and 1 flash per sequence, it is possible to achieve 8 acquisitions per second.

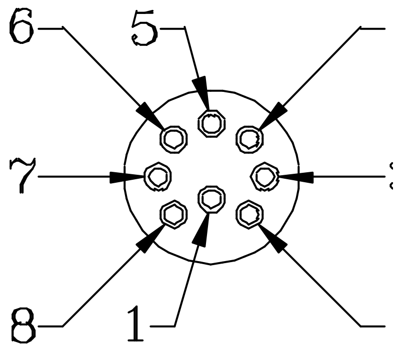
6. EXTERNAL CONNECTORS

The FAST*tracka* instrument has waterproof bulkhead connectors on both the instrument can and the battery can. Additionally, the battery can has a sealing plug which needs to be removed in order to access the battery charging receptacle.

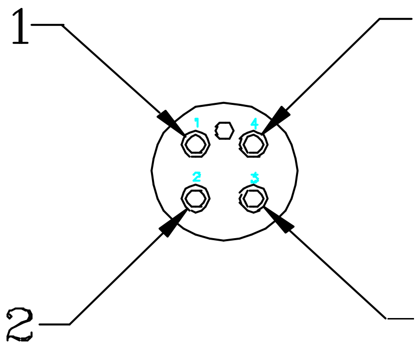
FAST*tracka* FRRF HOUSING INTERCONNECTIONS



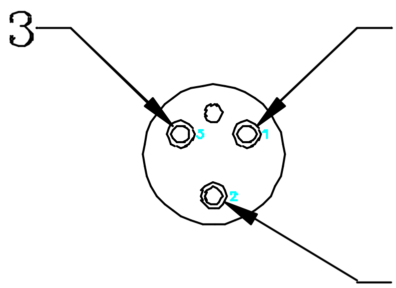
INTERFACE
BULKHEAD PLUG



AUXILLIARY
BULKHEAD SOCKET



PAR SENSOR
BULKHEAD SOCKET



BATTERY
BULKHEAD PLUG

6.1 INTERFACE CONNECTOR

Impulse BH-8-MP

Pin Description	
1. HOSTPWR+	18-72VDC 600mA @18V input
2. HOSTPWR(ret)	Host Power return
3. RXA	RS422 receive A input
4. RXB	RS422 receive B input
5. TXA	RS422 Transmit A output
6. TXB	RS422 Transmit B output
7. NC	No connection
8. CENTRAL GND	Central ground

6.2 AUXILLIARY CONNECTOR

Impulse BH-8-FS

Pin	Description
1. 0V	Pressure sensor 0V
2. HISIG	Pressure sensor high signal input
3. LOSIG	Pressure sensor low signal input
4. 12VOUT	Pressure sensor 12V supply output
5. F0	F0 signal output 0 - 5V
6. Fm	Fm signal output 0 - 5V
7. SIG RET	Signal return for F0
8. SIG RET	Signal return for Fm

6.3 BATTERY CONNECTOR

Impulse BH-3-MP

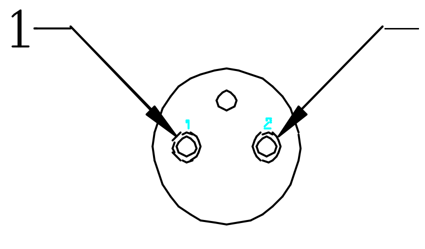
Pin	Description
1. BATT IN+	10.5 - 18VDC, 650mA @ 14V input
2. BATT RET	Battery power return
3. CTD detect	Connect to pin 1 for CTD operation

6.4 PAR SENSOR CONNECTOR

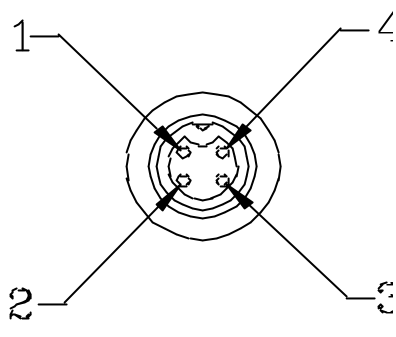
Impulse BH-4-FS

Pin	Description
1. 0V	Par sensor 0V
2. HISIG	Par sensor high signal input
3. LOSIG	Par sensor low signal input
4. 12VOUT	Par sensor 12V supply output

FAST*tracka* BATTERY HOUSING INTERCONNECTION



BATTERY INTERCONNECTION
BULKHEAD SOCKET



BATTERY CHARGING
BULKHEAD SOCKET

6.5 BATTERY CONNECTOR

Impulse BH-2-FS

Pin	Description	
1.	BATT OUT +	Battery positive output nominally 14V
2.	BATT RET	Battery negative output

6.6 BATTERY CHARGING SOCKET

Switchcraft EN3P4F

Pin	Description	
1.	CHARGE RET	Battery charger input return
2.	CHARGE IN	Battery charger input +28V
3.	CHARGE RET	Battery charger input return
4.	CHARGE IN	Battery charger input +28V

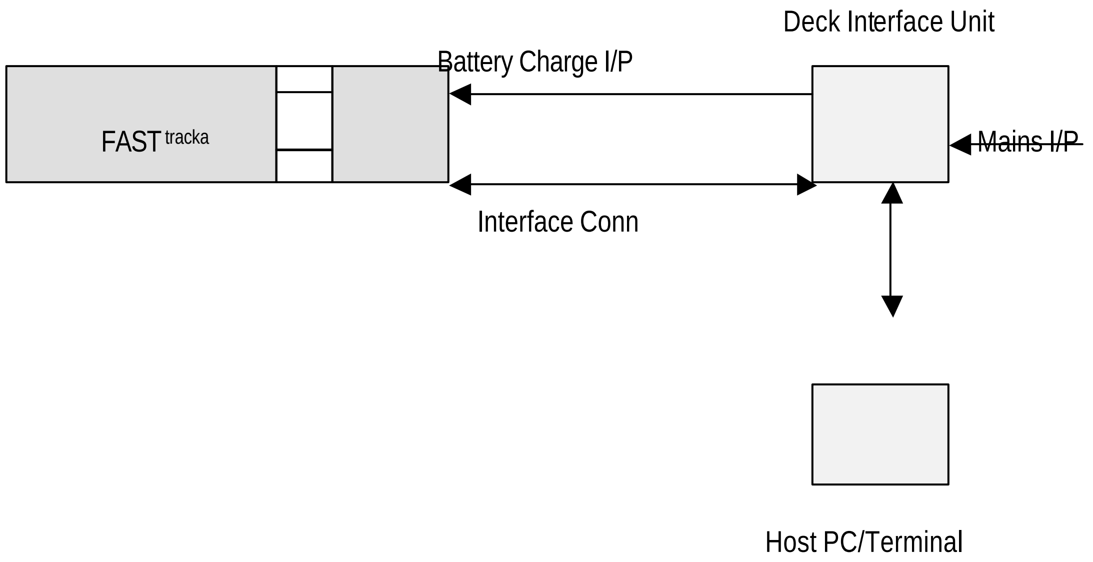
7. GLOSSARY

Flash Repetition Rate	The rate at which flashes occur in a flash sequence. (~200kHz)
Flash Sequence	A series of saturation and relaxation flashes (usually SFC = 100, DFC =20).
Flash	A single burst of light from LED flashlamps, on the order of microseconds.
Flash Sequence Rate	The rate at which flash sequences are repeated (up to 8 Hz).
Acquisition	Any combination of flash sequences which lead to one final set of FRRF data values. Several flash sequences may be averaged to produce one final acquisition.
Excitation Signal	The blue light from the LED flashlamp used to stimulate PSII. Also referred to as the Reference Signal.
Excitation Channel	One of two optical windows on the optical head from which the FRRF excitation light is delivered. These are labelled channel A and B.
Emission Signal	Any red light (fluorescence) observed from the phytoplankton, including both biological signal and contamination.
Emission Channel	The single optical path leading to the PMT from the optical head, having two optical windows, one for each excitation channel.
PMT	Photomultiplier tube, used in the emission optical channel to detect fluorescence.
Light Channel	The Excitation Channel open to solar illumination. Channel A is configured at the factory to be the Light Channel, and shows the indicator LEDs.
Dark Channel	The Excitation Channel shielded from ambient illumination by means of the dark chamber assembly. Channel B is configured at the factory as the Dark Channel, and does not have indicator LEDs.
Signal Contamination	Any fraction of the emission signal which does not result from chlorophyll fluorescence.
Saturation Flashes	Closely spaced, brief pulses of light generated by the FRRF to gradually saturate the phytoplankton photosystems. The factory default for these is 1 µs in duration, 1µs spacing (i.e. 50% duty cycle).

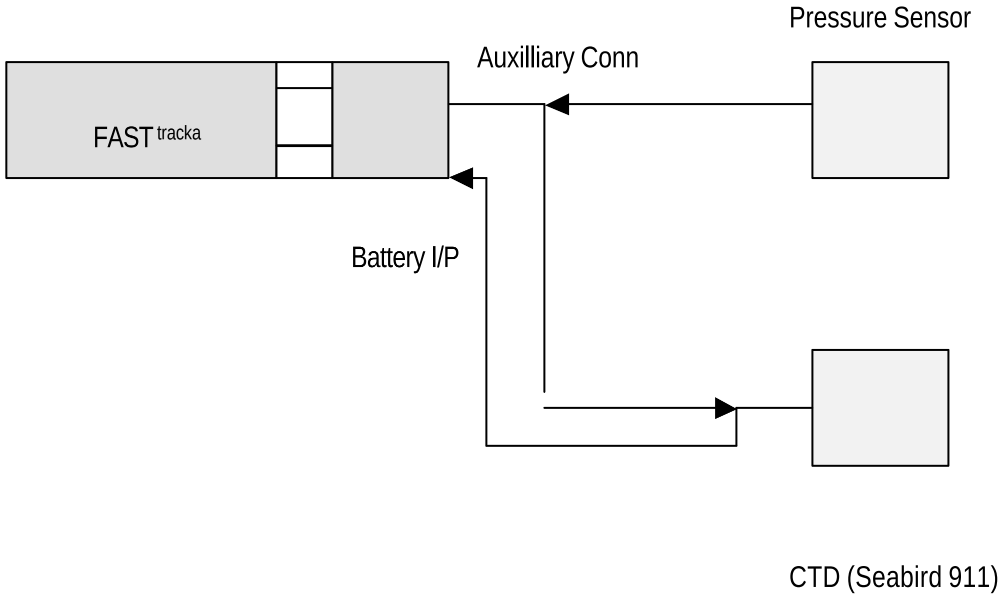
Relaxation Flashes	Widely spaced, brief pulses of light generated by the FRRF to gradually probe the phytoplankton photosystems after saturation in order to observe relaxation kinetics. The factory default for these is 1 µs in duration, 50 µs apart. Also referred to as Decay Flashes.

8. APPENDIX 1 - INTERCONNECTION DIAGRAMS

FAST*tracka* Interconnection Diagram for battery charging and host communication.



FAST*tracka* Interconnection Diagram for CTD operation and Pressure Sensor Option.



9. APPENDIX 2 - SERIAL COMMUNICATIONS

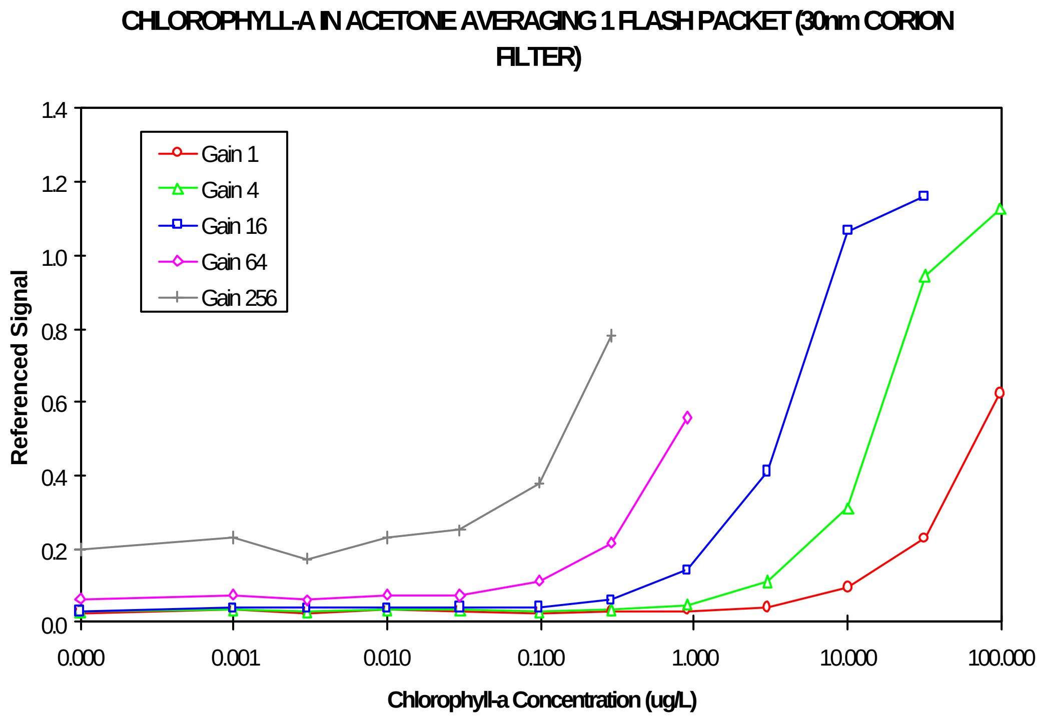
Improper configuration of the users' host serial terminal or PC terminal emulator is the most common source of problems with communicating with the FAST*tracka*. A series of hints and tips is included here to help the user troubleshoot their serial communication system before requesting assistance from CI Technical Support.

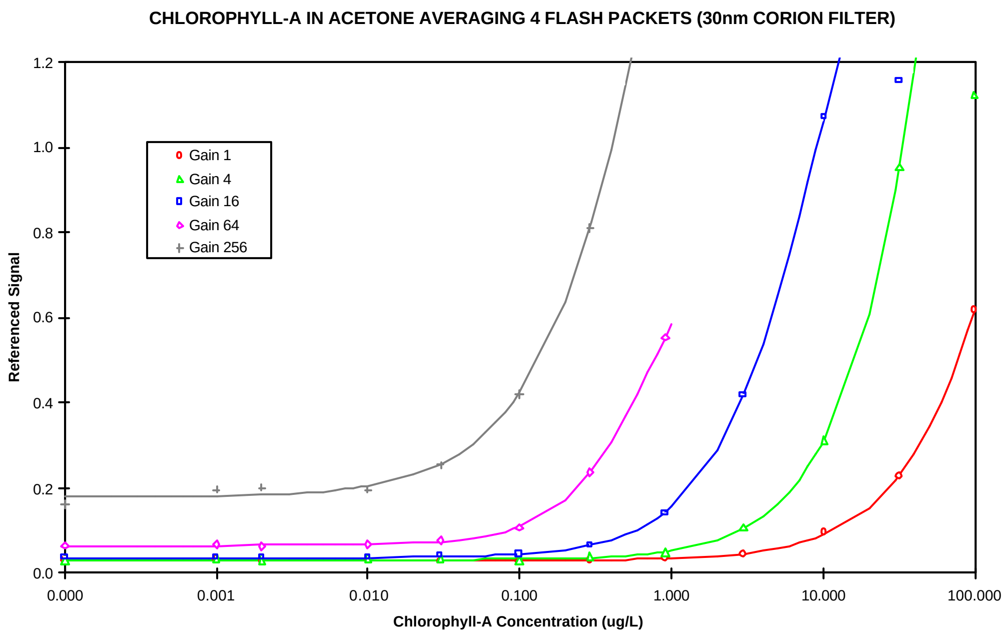
Basic Configuration:

1. The FAST*tracka* requires that the serial communication occurs with the following settings: 9600, N81. Ensure that the serial package or terminal device is set in this fashion by checking the appropriate options fields in the software package.
2. Ensure that the Interface cable is properly seated in the bulkhead connector. This seating can be checked by disconnecting the battery can to FRRF can external cable, unplugging the Deck Unit from mains, and attempting to wakeup the FAST*tracka* with the magnet switch. The FAST*tracka* should give indicator LED error codes representing no power (three short blinks). By plugging the Deck Unit into mains and repeating the wakeup, one long blink will indicate that the unit sees Deck Unit power through the Interface cable, and assumedly the serial connections as well.
3. Ensure that the serial port is properly set on the host PC. For a 9 way D sub connector, wire together pins 2 and 3. If you do not observe the appropriate character when typing a key, the terminal is not properly configured. Examples of such problems include: improper echo settings (multiple characters appear when typed), improper baud setting (garbled characters appear when typed) and improperly set serial port/IRQs (mouse action causes nonsense text to appear). Properly configure your terminal or terminal emulator by consulting your terminal manuals, remedy this problem and proceed with wakeup.

10. APPENDIX 3 - TYPICAL SENSITIVITY CURVES

Following three graphs show typical instrument sensitivity over PMT gain range and concentration of chlorophyll-a in acetone. The three curve sets illustrate the signal improvement when averaging the indicated number of flash sequences:





CHLOROPHYLL-A IN ACETONE AVERAGING 16 FLASH PACKETS (30nm CORION FILTER)