Highly Flexible Four-channel Current Electrometer with Dosimetry Control

Key features

- Four fully parallel multi-range I-V converters and ADCs
- Dynamic range 0.02 nA to 10.0 mA
- Integrated digitization and filtering
- Charge accumulation and dose control
- Analog monitor outputs
- Configurable analog and digital I/O
- Interlock relay outputs
- Configurable application-specific functions
- Ethernet interface with web server UI
- Optional high voltage output with loopback verification

Applications	• Quadrant ionization chamber readout • Quadrant photodiode and diamond readout • Dose delivery control • Beam stabilisation
Options	• Auxiliary HV output options up to +/- 2000V • Customer application specific software

Features and specifications - current measurement

Operating principle	Multi-range transconductance amplifier (I-V converter)
Number of channels	Four
Current ranges and analog bandwidth settings	Six current range settings, two with high bandwidth setting. Noise values rms of readings at stated averaging times.

Current range	*Analog -3 dB bandwidth DC to:*
100 nA	1 kHz
100 nA (high bandwidth)	10 kHz
1 µA	5 kHz
1 µA (high bandwidth)	50 kHz
10 µA	50 kHz
100 µA	50 kHz
1 mA	50 kHz
10 mA	50 kHz

High bandwidth low current ranges external capacitive load on input less than 1000 pF for stable operation

Features and specifications - current measurement (continued)

Input impedance	<= 130 ohm
Absolute accuracy	Readings within +/- 0.1 % full scale relative to a traceable external standard current source for >= one year after calibration.
Stability	Output drift < 20 ppm of full scale hr^{-1} + 10ppm of full scale C^{-1}
Digitization	16 bit successive approximation, up to 100 kSa/sec Four channels fully parallel.
Resolution enhancement	

Averaging time	*Data rate*	*Effective digitization*
(no averaging)	100 kHz	16 bit
1 msec	1 kHz	20 bit
10 msec	100 Hz	21 bit
16.7, 20 msec	60, 50 Hz	22 bit
100 msec	10 Hz	23 bit

Low current noise limits (100 nA range)

Standard deviation of repeat readings at the stated averaging time, unloaded inputs.

Averaging time	*100 nA range*	*100 nA high bandwidth range*
10 µsec	< 5 pA	< 15 pA
100 µsec	< 2 pA	< 5 pA
1 msec	< 1 pA	< 3.pA
10 msec	< 0.5 pA	< 1.5 pA
100 msec	< 0.2 pA	0.6 pA

Peak to peak spread of repeat readings at the stated averaging time, unloaded inputs.

Averaging time	*100 nA range*	*100 nA high bandwidth range*
10 usec	< 25 pA	< 75 pA
100 usec	< 15 pA	< 30 pA
1 msec	< 7 pA	< 10 pA
10 msec	< 2 pA	< 4 pA
100 msec	< 1 pA	< 2 pA

Scaling

Arbitrary scaling factor can be applied to each channel.

Scaling factor 0.0 allows selected channel to be turned off.

Features and specifications - current measurement (continued)

Triggering	External trigger can start, pause and stop acquisition via TTL digital input or fiber optic receiver.
Charge accumulation	Charge accumulation provided via numeric integration.
Data acquisition	Data collection and export to csv
Plotting	Measured current as a function of time with user controls for start/stop, axis scales, cursor.

Features and specifications - analog monitor outputs

Number and type	Four analog outputs, +/- 10 V
Resolution	16 bit over +/- 10 V
Maximum update rate	50,000 Hz
Functions	Default: - Track measured currents on each channel, mapped to full scale range. Other functions (software configurable via built-in arithmetic library): - Track charge - Arithmetic combination of measured currents (sum, difference, ratio) - Position functions (quadrant detector) - Process control output (PID controller)

Features and specifications - general purpose digital IO

Number and type	Four, TTL levels, each assignable as input or output, pull-up or pull-down (on expansion port)
Functions	Configurable control of external processes including dosimetry, information to external systems (examples: beam on/off, charge monitor unit pulses, PWM outputs, encoder inputs)

Features and specifications - fiber optics

Number	Three transmitters, three receivers, 850 nm light (near infra-red) suitable for 200 µm core or 62.5 µm step index HCS fiber, ST bayonet connectors. Transmission distance up to 1 km
Input function	Configurable monitor of external process, information from external systems (examples: trigger input, gate input, beam ready)
Output function	Configurable control of external process, information to external systems (examples: beam on/off, charge monitor unit pulses)

Features and specifications - relays

Number and type	Two independent solid state relay outputs normally open, each comprising two contacts in series for reliability. 1.0 A maximum current, 24 V logic. Relays independently configurable according to one or more permits, for example to define multiple conditions that must apply to allow dose delivery when in dosimetry mode.
On resistance	< 0.5 ohm
Open/close time	Close: 0.6 sec typical. Open: 0.06 sec typical
Output function	Safety interlocks (examples: beam interlock, beam on/off)
Watchdog	Watchdog timeout latches to prevent relay closed state (both relays).

Features and specifications - high voltage option

Number and type	One optional internal HV supply, voltage options +/- 100, 500, 1000, 2000. Maximum voltage and polarity specified at time of order. HV loopback feature confirms voltage reaches external electrode.
Compliance	1 W maximum output power
Monitoring	Output voltage, 12 bit resolution Loopback voltage, 12 bit resolution
Control	Software control of HV enable and voltage setting

Features and specifications - physical

Case material	Stainless steel sheet
Protection rating	IP32 (higher rating enclosure option available as custom build)
Dimensions	197 x 137 x 50 mm overall approx. (see figures)
Weight	1.04 kg (2.3 lb).
Operating environment	10 to 40 C (15 to 25 C recommended to reduce drift and offset) , < 70% humidity, non-condensing, vibration < 0.1g all axes (1 to 100Hz) Vibration must be as low as possible to measure at the lower limit of the dynamic range.
Shipping and storage environment	-10 to 50C, < 80% humidity, non-condensing, vibration < 2g all axes, 1 to 100Hz

Features and specifications - processor, interface, operating system

Processors	AM335x ARM Cortex A8 1 GHz primary processor Floating point accelerator Two 32-bit PRU microcontrollers
Memory	512 MB DDR3 RAM 4 GB eMMC flash NVR 32 GB SD card for application software
Operating system	Blackberry QNX real-time operating system. Pre-certified version to IEC 62304 medical safety purchase option.
Host computer interface	Ethernet 10/100, TCP/IP

Features and specifications - diagnostic display

Type	240 x 240 pixel colour TFT
Functions	Display of user-assigned device name Display of network connection details Firmware version Display of summed current, HV output, relay states

User interface

Types	Embedded web server Accessible from any web browser software running on any platform. Windows network discovery using Universal Plug and Play (UPnP)  Embedded EPICS IOC

Integrated applications - Dosimetry

Function	Integrate currents on sum of all or a subset of channels up to a user-defined target charge. Allows single control point (scattering systems) or multiple control points (spot scanning systems). Target dose can be defined in charge units or user-definable monitor units (MU).

Beam control via fiber optic, digital signals or relays.

User-definable states and permissions to start, pause and stop dosing.

User-definable multiple beam interlock conditions (latching or non-latching) including :

- pre-irradiation safety check not completed successfully
- time limit exceeded
- HV out of tolerance
- beam position out of tolerance
- dose rate out of tolerance band
- excess dose when beam commanded off

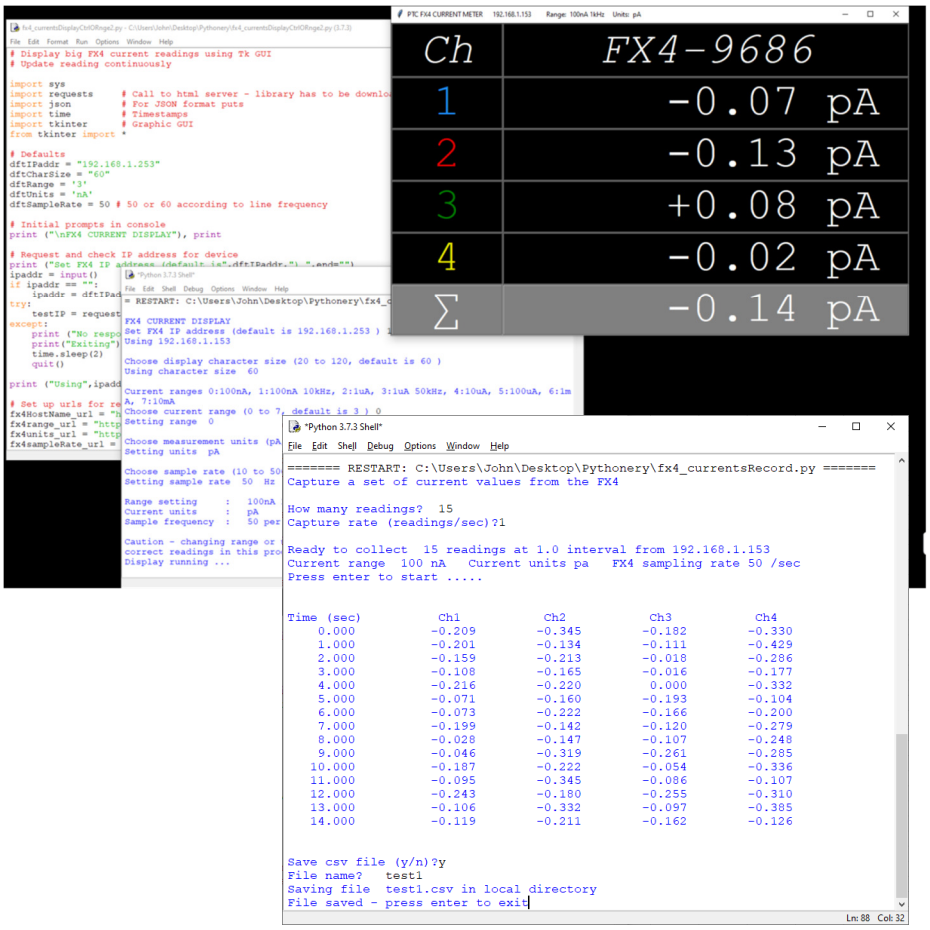
Acquisition parameters locked out when dosimetry active.

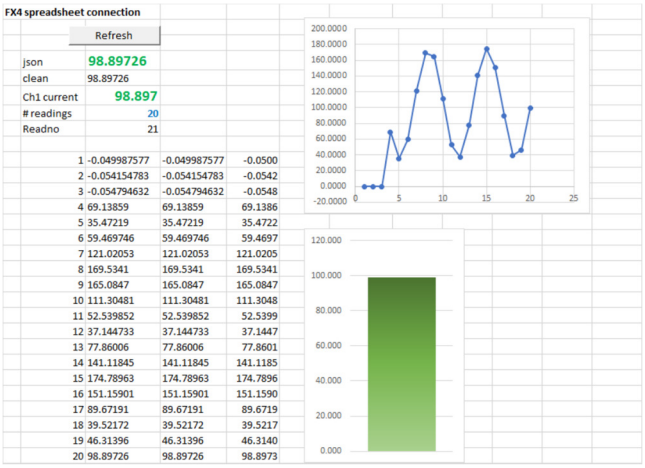
Definable charge monitor pulse output via digital outputs and/or fiber optic to allow independent verification of delivered dose.

Beam current and/or accumulated charge can be tracked by analog monitor outputs for independent verification of dose rate and total delivered dose.

User API

Methods	REST API: JSON HTTP, WebSockets, or EPICS. Compatible with most popular programming languages.
Python	Example connection via JSON HTTP or via pyEPICS channel access
Excel	Connection using Microsoft Webservice function





Connectors

Signal inputs	Four BNC jacks isolated from chassis (screen is circuit analog ground).
Monitor output s	Four BNC jacks isolated from chassis. (screen is circuit analog ground).
HV out	SHV
HV loopback	SHV
Expansion port	DSub 9 pin female

1	Digital out 1 GPIO	6	I2C SCL clock out
2	Digital out 2 GPIO	7	I2C SDA data bidirectional
3	Digital out 3 GPIO	8	3.3 VDC out
4	Digital out 4 GPIO	9	Gnd rtn for 5.0, 3.3 V
5	5.0 VDC out	Scrn	Chassis ground

Digitals 1-4 are bidirectional, usable for PRU, GPIO, UART, CAN, encoders, PWM.

D1: UART 1 RX, CAN TX, Enc A, PWM 1A D2: UART 1 TX, CAN RX, Enc B, PWM 1B
D3: UART 2 RX, Enc index, PWM 2A D2: UART 2 TX, PWM 2B

Relay outputs

Phoenix Combicon DMC8 pin header 1787030 3.5 mm

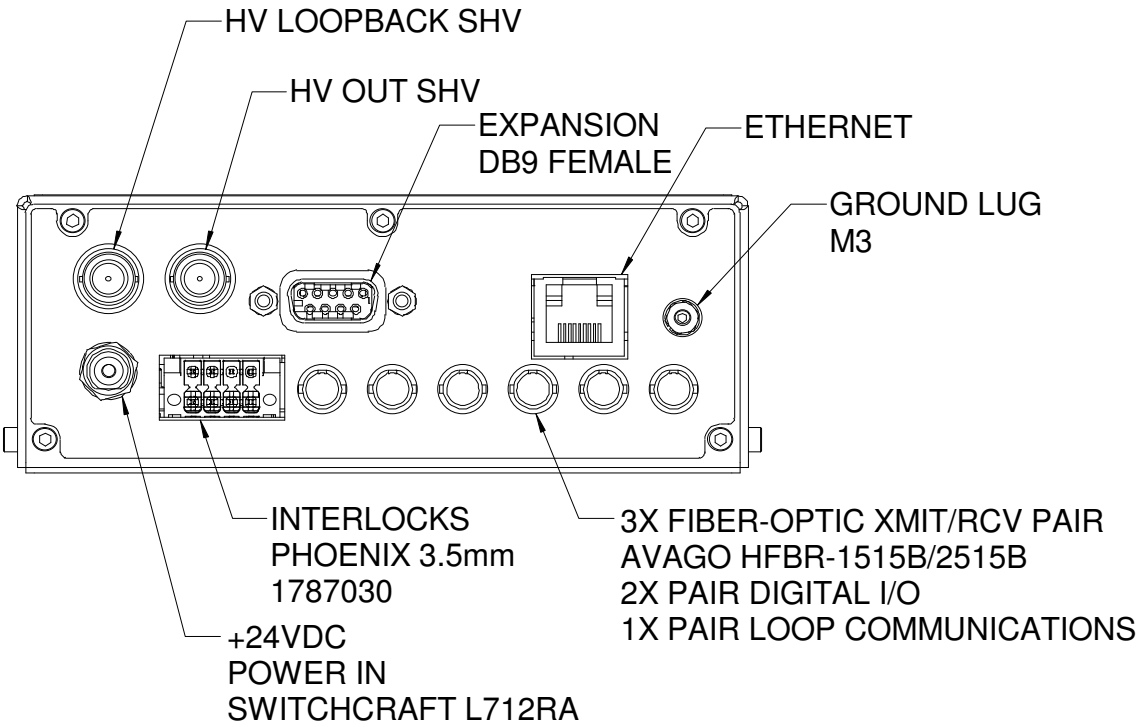
1	+24 V fused	5	+24 V fused
2	24 V rtn	6	24 V rtn
3	Relay 1 contact A	7	Relay 2 contact A
4	Relay 1 contact B	8	Relay 2 contact B

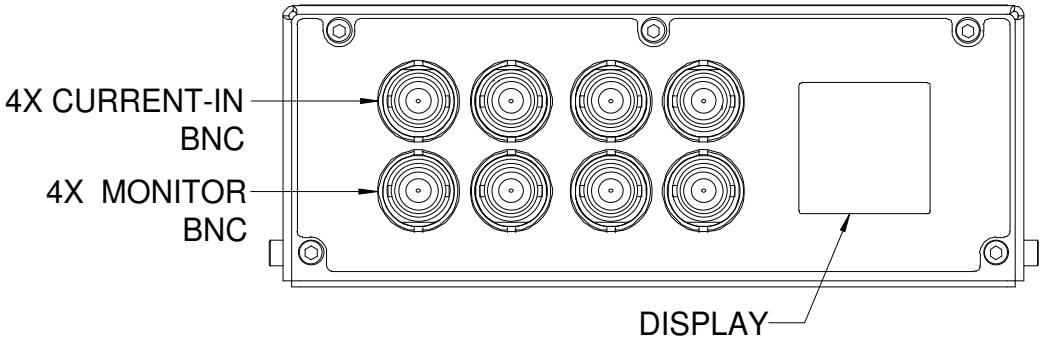
Mating connector is included
24 V outputs pins 1,5 have combined fuse rating 200 mA.

Fiber optics

Three fiber optic transmitters ST bayonet connectors light grey(HFBR-1515)
Three fiber optic receivers ST bayonet connectors dark grey (HFBR-2515)
Two pair assigned to digital I/O, one pair assigned to fiber optic serial communication with remote devices.
Recommended cable: hard-clad silica 200 µm core, 230 µm cladding, 2.2 mm jacket (OFS BC035597-10 BL or OFS BC04265-10)
Recommended connectors: crimp connector (OFS BP05065-12 using termination kit OFS DT03732-32).

Ethernet	RJ-45 jack
Power	Switchcraft 2.1 mm threaded jack L721, +24 V on central conductor, 24 V return on sleeve. Mating connector Switchcraft S761K
Ground lug	M3 threaded stud.





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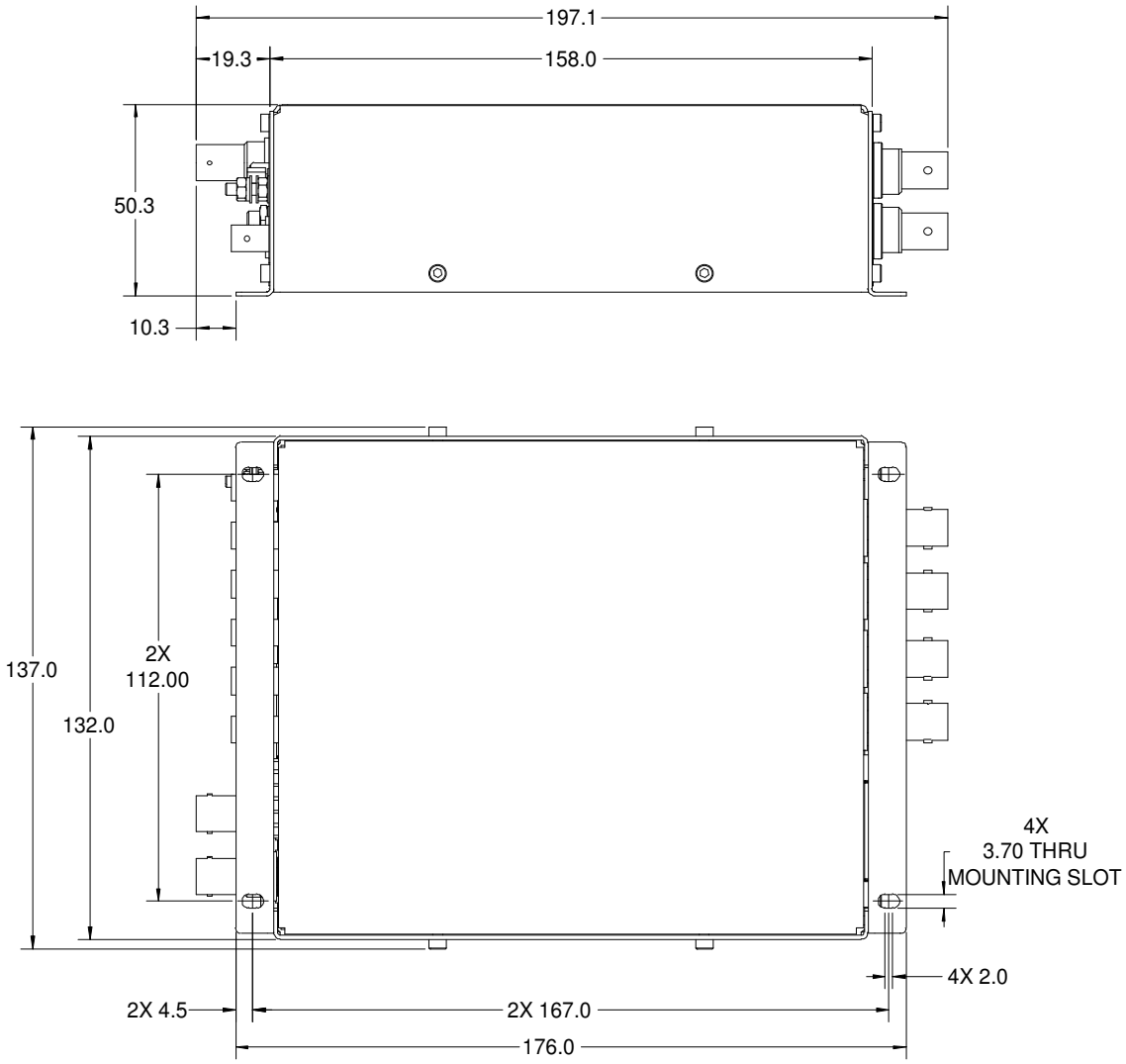

Dims mm

Ordering information

FX4	FX4 four channel electrometer, user manuals, software drivers, calibration data.
-XP20/10/05//02 (-XN)	Add HV bias supply positive 2000 / 1000 / 500 / 200 V (negative)
Example:	FX4-XN05 FX4 electrometer with -500 V HV bias supply fitted.