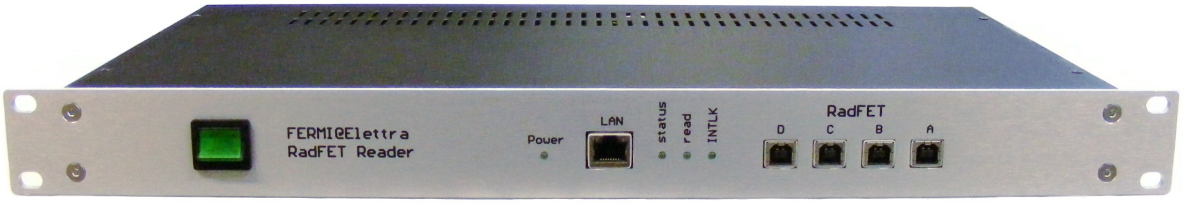
2012-01-11



DOSFET-L01

reader for MOSFET dosimeters

operating instructions

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2012-01-11 — Initial revision for firmware 1.16

Contents

1. Introduction

The DOSFET-L01 Reader is a complete readout solution for a wide range of electronic MOSFET dosimeters.

It is well known that MOSFETs are susceptible to ionizing radiation. The main reason for this is the insulating oxide layer separating the gate electrode from the semiconductor. Under irradiation, electrons are removed from this layer and leave behind a positively charged region.

Under normal conditions, only little recombination takes place, and the positive charges remain trapped in the oxide layer for many years. This space charge screens the electric potential of the gate electrode and thus changes the electrical characteristics of the transistor.

The DOSFET-L01 measures this change by injecting a constant current of 490 μA between the source and the drain electrodes. The voltage needed to drive this current is a measure of the total ionizing dose the MOSFET has received. It typically ranges from fev volts for an unirradiated dosimeter to more than 10 V for one that has been exposed to several kGy of dose.

The DOSFET-L01 was developed for the monitoring of radiation dose on permanent undulator magnets in the framework of the FERMI@Elettra project.

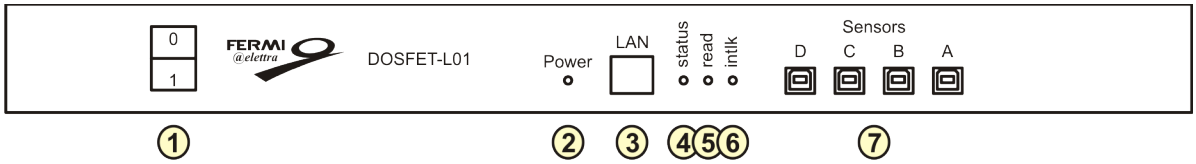
2. Device Overview

This chapter gives an overview of the dimensions, various ports, indicators and controls of the DOSFET-L01.

Form factor

The DOSFET-L01 is designed for installation in a standard 19″ rack. The width of the main enclosure is 44 cm, the front panel is 48.3 cm wide. The device has a height of 4.5 cm (1 rack unit) and a total depth of 24.8 cm.

Front panel



1 — On/off switch (lights up when device is switched on)

2 — Power LED (lights up when electronics is supplied with +5 V DC)

3 — LAN port (10/100 Mbit/s Ethernet over RJ45/8P8C modular connector)

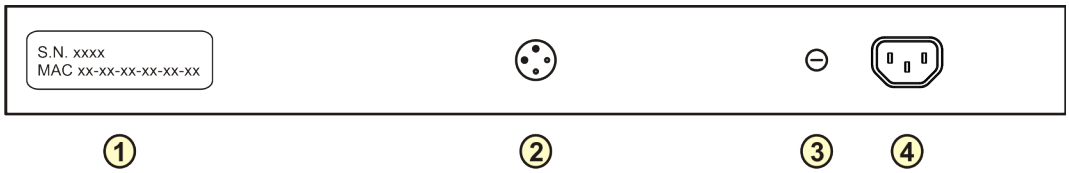
4 — Status LED (blinks periodically while device is in wait state)

5 — Read LED (lights up when a read-out operation is in progress)

6 — Interlock LED (reserved for future use)

7 — Sensor ports A–D (USB-style ports for the connection of MOSFET sensors as described in chapter 5.; **connecting a USB device to any of these ports may cause damage to the device and the DOSFET-L01**)

Rear panel



1 — Serial number sticker (contains the serial number and the MAC address)

2 — Interlock port (reserved for future use)

3 — Fuse

4 — Mains inlet (AC 230 V/50 Hz)

Power requirements

The required mains voltage is 230 V (AC) at 50 Hz. The device consumes less than 25 W of electrical power.

3. Important Notes

The DOSFET-L01 contains sensitive reed relays. To ensure the correct functioning of the device, do not expose it to strong magnetic fields. Protect it from severe shocks and extreme temperatures.

4. Principle Of Operation

Metal oxide field-effect transistors (MOSFETs) change their electrical characteristics under irradiation. The main cause for this is the trapping of positive charges in the gate oxide layer. Depending on the construction of the MOSFET sensor and on external factors (like temperature), the positive charge can remain fixed for years. This makes the transistor usable as an integrating dosimeter.

To extract dosimetric information from a MOSFET sensor, the DOSFET-L01 measures the so-called threshold voltage V_t for a fixed current of $I_{inj} = 490\ \mu A$. This current is injected between the source and the drain electrode of the MOSFET while the gate is kept at ground potential. The voltage V_t necessary to drive the current is measured with a high-precision ADC. V_t increases with the total radiation dose absorbed by the sensor.

Fig. 4.1 illustrates the measurement principle used by the DOSFET-L01 and the connection scheme for a typical 2-MOSFET sensor using the "RADFET mount" adapter board included with the device. A 30 V DC voltage source, a high precision voltage reference (V_{ref}) and components R1, U2, and Q1 work as a precision constant current source. At the exit of this current source, the voltage is fed to a 24 bit ADC via U4.

After this point, the current I_{inj} takes different paths according to the operational state of the DOSFET-L01. The following sums up a typical operation cycle:

1. *Passive (irradiation) state:*
   I_{inj} is dumped to a load resistor via Q2. In this way the voltage at the exit of the constant current source is limited to a reasonably low value. All electrodes of the sensor are grounded (with the exception of one drain electrode in the case of a 2-MOSFET sensor, which is left unconnected).
   • Q2 is conductive.
   • K1 is switched to ground.

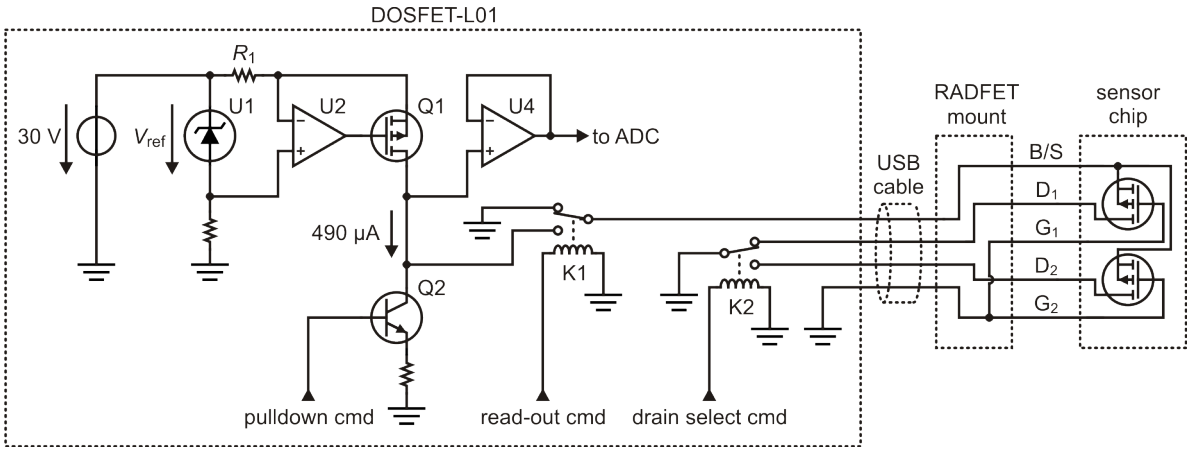


Fig. 4.1: Simplified schematic of a single DOSFET-L01 channel and its connection to a dual MOSFET sensor via USB cable and "RADFET mount" board

2. *Switch-over to read-out state:*
   While the voltage is held low by Q2, the relay K1 closes and connects the sensor source electrode(s) to the circuitry.
   • Q2 is conductive.
   • K1 is closed.

3. *Read-out state:*
   The transistor Q2 is no longer conductive, so I_{inj} flows through K1 to the MOSFET sensor and returns through K2 to ground. K2 can be used to direct the current through one of two MOSFETs on the sensor. Once the device has entered the read-out state, digitization starts after a delay of typically few milliseconds. This read delay can be changed with the SETDELAY command.
   • Q2 is non-conductive.
   • K1 is closed.
   • K2 connects the drain electrode of one sensor MOSFET to ground.

4. *Switch-over to passive (irradiation) state:*
   After the digitization has taken place, Q2 becomes conductive again to reduce the output voltage of the current source while the relay K1 is still closed. After a very short time in this state, the DOSFET-L01 returns to the passive state 1.
   • Q2 is conductive.
   • K1 is closed.

The DOSFET-L01 natively supports sensors with one or two MOSFETs. The following chapter gives indications on how to correctly connect a sensor.

5. Connecting A Sensor

The DOSFET-L01 is shipped with four small "RADFET mount" boards that allow the connection of "RADFET RFT-300-CC10G1" sensors from REM Oxford Ltd.[1] via a standard USB cable with a "type A" and a "type B" connector. The boards can be mounted to external supports with an M5 screw.

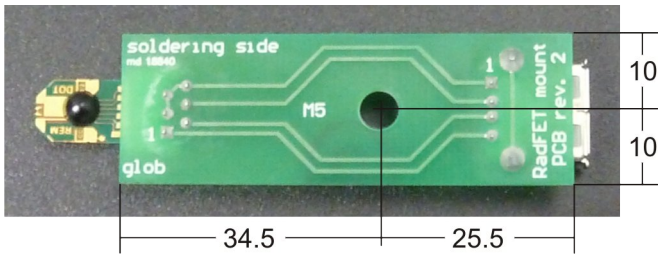


Fig. 5.1: RADFET mount with correctly inserted RFT-300-CC10G1 sensor (dimensions in mm)

The boards are marked with the label "glob" on one side. The RADFET sensor has to be inserted with the black epoxy globule on this side as shown in Fig. 5.1. **Operation with an incorrectly (reversely) inserted sensor can cause damage to the sensor and the reader.**

A description of the contacts is found in Tab. 5.1. If a sensor is to be connected without the RADFET mount, e.g. by soldering it directly to a USB cable, the standard colors of the respective wires inside the cable may give some orientation. For further details please refer to chapter 4.

RADFET pin	USB pin	USB wire	Signal
3, 5, 6	1	red	GND
4	2	white	D2 (drain of FET 2)
2	3	green	D1 (drain of FET 1)
1	4	black	S+B (source+bulk)

Tab. 5.1: Pinout of the RADFET Mount PCB

1 REM Oxford Ltd., 64A Acre End St., Eynsham, Oxford OX29 4PD, UK (http://www.radfet.com)

6. Control Interface

TCP/IP Connectivity

By default, the DOSFET-L01 communicates with a single client at a time using TCP port 10001 and IP address 192.168.243.243. For information on how to change port and/or address, please refer to chapter 8.

Reader Output

To understand the way the reader communicates its measurements, you can connect to it with a standard Telnet client on port 10001. To trigger a measurement on all four channels, press Return, type the command GETDATA, and press Return again. The DOSFET-L01 should produce an output like this:

```
Reader 11  Acquisition 147  Sensor A  Drain 1  00110001100001001111111100010010  ERANGE  293928722  27374 mV
Reader 11  Acquisition 147  Sensor B  Drain 1  00110001100000000111011000100110  ERANGE  293631526  27346 mV
Reader 11  Acquisition 147  Sensor C  Drain 1  00110001100000100011101011101101  ERANGE  293747437  27357 mV
Reader 11  Acquisition 147  Sensor D  Drain 1  00110001011111100101011011011101  ERANGE  293492445  27334 mV
Reader 11  Acquisition 147  Sensor A  Drain 2  00110001100001001110010111000100  ERANGE  293922244  27374 mV
Reader 11  Acquisition 147  Sensor B  Drain 2  00110001100000000110100001100001  ERANGE  293628001  27346 mV
Reader 11  Acquisition 147  Sensor C  Drain 2  00110001100000100001101101010110  ERANGE  293739350  27357 mV
Reader 11  Acquisition 147  Sensor D  Drain 2  00110001011111100100110101100100  ERANGE  293490020  27333 mV
```

Each connected sensor can contain two MOSFETs which are selected by the reader via their drain connection, hence there are 8 lines of output. The columns have the following meaning:

1. “Reader 11”: Serial number of the reader
2. “Acquisition 147”: Sequence number of the measurement
3. “Sensor A”: Selected sensor channel (see labels on the front panel)
4. “Drain 1”: Selected drain (i.e. which MOSFET on the sensor is read)
5. “0011...”: Raw ADC bit sequence (for debugging purposes)
6. “ERANGE”: State of the readout:

OK	Correct reading
ERANGE	Voltage exceeds ADC specifications
ERROR	Unable to read

7. "293490020": Voltage in ADC units (full accuracy)
8. "27333 mV": Voltage in mV (with limited accuracy)

For a precise evaluation of the voltage, field 7 should be used instead of field 8. The value A in ADC units can then converted to a voltage U using:

$$U = \frac{A}{2^{28} - 1} \cdot 25\,\mathrm{V}$$

Command reference

The following commands are available (in Telnet, enter the command, then press Return):

GETDATA	Triggers a read-out of all sensors (see previous section).
GETVERSION	Prints the firmware version.
GETPERIOD	Prints the readout period in seconds.
SETPERIOD *n*	Configures the DOSFET-L01 to automatically perform a read-out every *n* seconds. The output format is identical to GET-DATA. The first read-out will occur immediately after the command. The minimum period is 10 seconds. "SETPERIOD 0" disables the automatic read-out.
GETDELAY	Prints the read delay in milliseconds.
SETDELAY *n*	Sets the read delay to *n* milliseconds. The read delay is the time between the transistor Q2 becoming non-conductive and the start of the digitization. The default value is *n* = 5 ms, the minimum 1 ms, the maximum 30000 ms = 30 s. Delays above few seconds are not recommended, however, because the DOSFET-L01 does not respond to commands during the read-out process. The read delay is applied during the read-out of each single MOSFET, so the total read-out time multiplies accordingly. For details on the read-out sequence please refer to chapter 4.

Automated readout

The DOSFET-L01 can perform a single read-out of the attached dosimeters via the GETDATA command or an automatic, periodic read-out via the SETPERIOD command. Display and logging of the data are normally performed by a dedicated client application that connects to the DOSFET-L01 via Ethernet. A simple data logger written in C++ is available in source code and can be used as a starting point to develop custom clients. A complete server environment for the Tango control system has also been developed.

7. Calibration

Voltage calibration

The individual sensor channels A–D of the DOSFET-L01 may have slightly different characteristics. For enhanced precision, an individual calibration factor C can be applied to the voltage V read by the device:

$$V_{\mathrm{A,corr}} = C_{\mathrm{A}} V_{\mathrm{A}}$$
$$V_{\mathrm{B,corr}} = C_{\mathrm{B}} V_{\mathrm{B}}$$
$$V_{\mathrm{C,corr}} = C_{\mathrm{C}} V_{\mathrm{C}}$$
$$V_{\mathrm{D,corr}} = C_{\mathrm{D}} V_{\mathrm{D}}$$

A list with calibration factors is supplied with each DOSFET-L01.

Conversion to dose

The reader does not provide a direct readout of the dose. Choosing a correct calibration curve is the responsability of the user.

For RFT-300-CC10G1 sensors from REM Oxford Ltd. irradiated under zero bias, we propose to use the function

$$D(\Delta V) = \exp\left(-\frac{b}{2c} - \sqrt{\frac{b^2}{4c^2} + \frac{\ln(\Delta V) - a}{c}}\right)$$

with

$$a = -4.33139, \quad b = 1.05947, \quad c = -0.04047 .$$

The function represents a fit to a series of yet unpublished calibration measurements.

8. Ethernet Interface Configuration

The DOSFET-L01 uses a Lantronix XPORT[2] device server as Ethernet interface. This chapter contains basic information on the correct configuration of the interface. For more details, please refer to the manufacturer's homepage:

http://www.lantronix.com

IP address

By default, the DOSFET-L01 uses the IP address 192.168.243.243. It can be changed to another static or dynamic (DHCP) address using a web interface (http://192.168.243.243/). The default username and password for the web interface are empty.

Alternatively, the LAN port can be configured using the *DeviceInstaller* software from Lantronix, available from the website http://www.lantronix.com/. The MAC address of the LAN port is noted on a sticker at the back of the device.

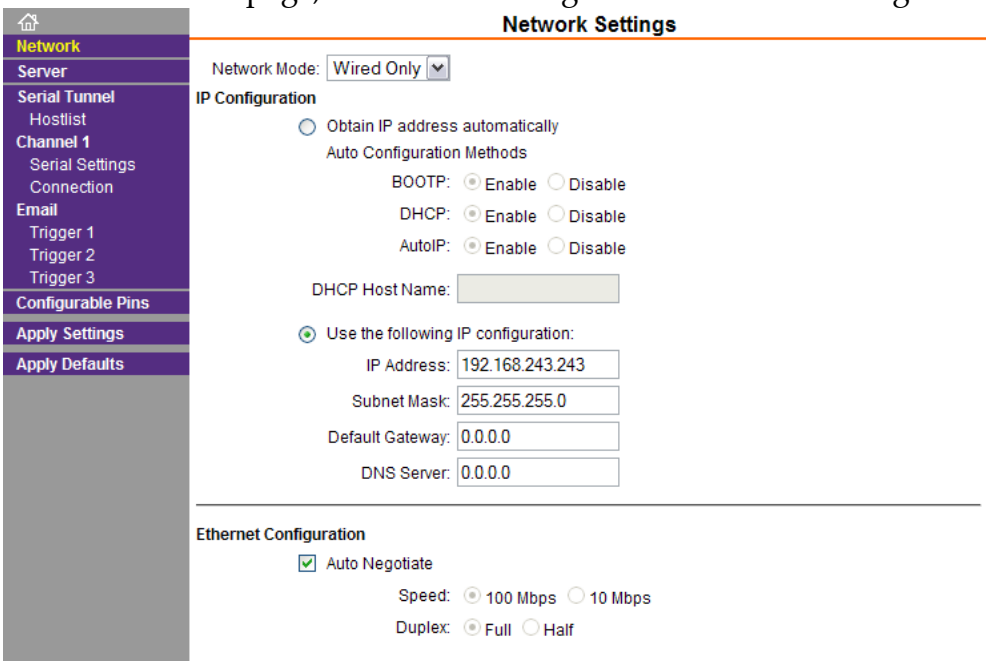
Device server configuration

A new DOSFET-L01 comes with a completely configured interface. With the exception of the IP address and port number, changes to the configuration are not recommended. If necessary, the following steps should help to restore the default configuration:

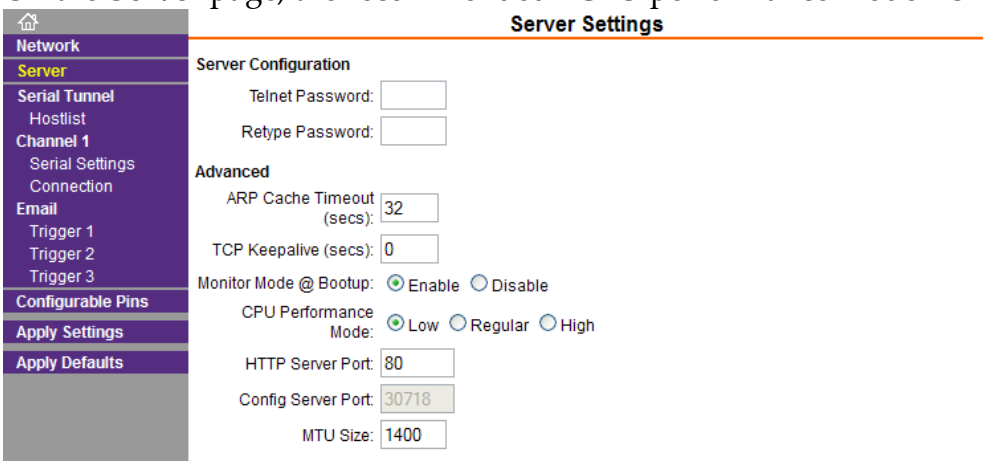
1. Open the web interface in a web browser (http://<ip_address>/). The default username and password for the web interface are empty.

2 XPort is a trademark of Lantronix, Inc. (http://www.lantronix.com)

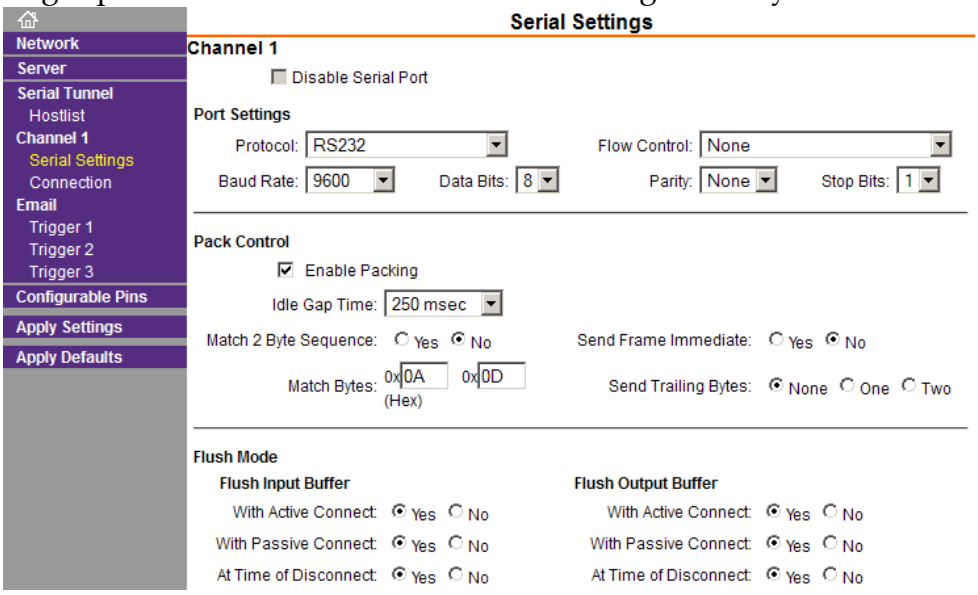
2. On the **Network** page, the default configuration is the following:



3. On the **Server** page, the recommended "CPU performance mode" is "low".



4. Any deviation from the following settings under **Channel1/Serial Settings** might prevent the DOSFET-L01 from working correctly:



5. These are the recommended settings under **Channel1/Connection**: