Operating Electronics
for Spectral Sensors
and Linear Image Arrays

8 Channel Electronic Spectral Sensor Multiplexer MUX-8A

Technical Documentation

Board: **MUX-8A (06303.10)**
PLD: **Programming Standard ‘A‘, Version V1.0**
Document: **Part ‘M8’, Version 1.00_E, 31.08.01 16:29**

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M8. Spectral Sensor Multiplexer MUX-8A

Content

M8.1 General

In conjunction with the Front End Electronics FEE-HS the Electronic Spectral Sensor Multiplexer MUX-8A allows to operate up to 8 identical sensor units (PDAs with preamplifier electronics or Spectral Sensors based on these arrays) with one Operating Electronics in a 'simultaneous' or 'sequential' mode.

In mode of operation ‚sequential', the multiplexer acts like a static input switch for up to 8 sensor modules attached. The size of a spectral data array is equal to the number of pixels of the active sensor.

In the operation mode 'simultaneous', a predefined combination of two to eigth sensors can be read out almost concurrently with the MUX-8A. To achieve this, the multiplexer interleaves the spectral data of the single sensors pixel by pixel. So, the scans are overlapping with a time shift of only one pixel readout clock (approx. 5 µs with FEE-HS). The selectable combinations are Ch1&Ch2, Ch1&Ch2&Ch3, Ch1&Ch2&Ch3&CH4 until Ch1&Ch2&Ch3&CH4&Ch5&Ch6&Ch7&CH8. The size of a spectral data array is equal to the sum of the number of pixels of all the active sensors.

The multiplexer operating mode (the active sensor or the combination) is selected by software and transferred to the MUX-8A via the Front End Electronics of the Operating Electronics.

M8.2 Concept

The active multiplexer subassembly acts as a kind of input multiplexer and is connected to the input of the Front End Electronics, a part of the Operating Electronics. The multiplexer links one Spectral Sensors or a combination of up to eight sensors to the Operating Electronics. Its function is software programmable. The Operating Electronics controls spectral data acquisition and forwards the data to a computer.

In the signal chain following the multiplexer data from all sensors pass identical circuitry for video data processing and analog-to-digital conversion, so that all measurement channels are influenced in an identical manner by potential electronics inaccuracies.

MUX-8A is called 'active' because the electronics has its own preprogrammed scan controller (Programmable Logic Device).

M8.3 Functional Characteristics

- Electronic Spectral Sensor Input Multiplexer, active
- Inputs for 1 to 8 sensors
  (Sensor interface type *'Sensor_1A'*)
- For MMS or MCS sensors of Carl Zeiss
- For Hamamatsu diode arrays of series S3901 to S3904, operation by tec5 preamplifier DZA-S3901-4
- Operating modes: sequential or simultaneous
- Operating mode control: software programmable
- E2PROM at I2C Bus for automatic configuration recognition

M8.4 Identification and Operating Modes

Definition of terms:

A scan cycle comprises

- for single scan (timer mode of operation 'TimerSingle') a
  - dummy scan (array reset),
  - wait for integration time (reduced by the read-out time) and
  - data scan (readout spectral information)

- for multiple scan (timer mode of operation 'TimerContinuous', autonomously repeated scanning) a sequence of
  - wait for integration time (reduced by readout time) and
  - data scan (in this case the previous data scan serves as a 'dummy scan' to reset the array).

As an example, the time required for reading out one spectrum of 256 pixels is some 1.4 ms at a pixel transfer rate of 187.5 kHz (clock rate of FEE-HS). In this case, the readout time per pixel is 5.3 µs.

M8.4.1 Identification

If a multiplexer module is plugged onto the Front End Electronics, it forwards its identification information to the scan controller via the two multiplexer status signals Multiplexer-ID0 and Multiplexer-ID1.

MultiplexerID1	MultiplexerID0	Condition
1	1	No multiplexer attached
1	0	Passive MUX-4P attached
0	1	Active MUX, type tbd. attached
0	0	Active MUX-8A attached

M8.4.2 Operating Modes

The sequencer logic on the MUX-8A board supports the two scan modes ‚sequential' and ‚simultaneous'.

The mode and channel selection is accomplished by the PC via the serial I2C Bus. The Front End Electronics receives the I2C multiplexer control data from the PC and transforms the information to 4 discrete control signals for the multiplexer. These control signal are: 3 channel select lines MUL_SEL0 ... MUL_SEL2 plus the operating mode control signal MX_MODE.

M8.4.2.1 Operating Mode 'Sequential' (Scan Multiplex)

In the sequential mode of operation (scan multiplex), the multiplexer acts like an interface switch for 8 sensor input channels.

Mode sequential, active channel	Multiplexer Mode MX_MODE	MUL_SEL2	MUL_SEL1	MUL_SEL0
CH1	0	0	0	0
CH2		0	0	1
CH3		0	1	0
CH4		0	1	1
CH5		1	0	0
CH6		1	0	1

CH7		1	1	0
CH8		1	1	1

All scan control signals of the Interface Electronics (StartOfScan, pixel clock) are provided to all sensors in a parallel way. Only the output signals of the selected sensor (EndOfScan, Video) are transferred to the Interface Electronics.
The PC program determines the timing and access sequence of the individual Spectral Sensors.

Characteristics:

- interface selector switch for a maximum of 8 sensor channels
- all sensors are operated synchronously
- with each scan cycle, data originated from the program-selected sensor are stored, the data acquired by the other sensor(s) at the same time are lost
- the channel switching is done by the software, therefore the temporal shift between two usable scans depend on the computer performance and corresponds to at least one measurement cycle

M8.4.2.2 Operating Mode 'Simultaneous', Version ‘A‘

In the simultaneous mode of operation (pixel multiplex), the control signals generated by the Operating Electronics (StartOfScan, pixel clock) are fed to the sequencer logic of the multiplexer subassembly.

This logic simulates an n-fold pixel count to the Interface Electronics (with n being the number of sensors attached or scanned). In contrast to the sequential mode of operation, the multiplexer input is switched from sensor to sensor for each pixel within the scan rather than once per scan. The sequence is initiated by the StartOfScan signal from the Interface Electronics. The sequencer then performs continuous pixel cycles, within each pixel cycle all active sensors are addressed internal in their sequence and clocked once. The scan cycle is finished as soon as each activated sensor has forwarded an EndOfScan signal to the sequencer. In this way, the measurement cycles are overlapping, with a time shift of one pixel read-out cycle (approx. 5 µs) per sensor.

At the simultaneous mode of operation, the readout sequence and the number of active sensors is defined by the PLD design on the multiplexer board. The electronic Spectral Sensor multiplexer MUX-8A is supplied at the moment with one scan sequence only (version ‘A‘).

Mode Simultaneous, scan combination	**Multiplexer Mode MX_MODE**	**MUL_SEL2**	**MUL_SEL1**	**MUL_SEL0**
CH1	1	0	0	0
CH1 & CH2		0	0	1
CH1 … CH3		0	1	0
CH1 … CH4		0	1	1
CH1 … CH5		1	0	0
CH1 … CH6		1	0	1
CH1 … CH7		1	1	0
CH1 … CH8		1	1	1

Characteristics:

- all sensors selected are read out simultaneously in each illumination cycle
- a simultaneous scan acquires data from all the active sensor channels (see table above)
- inactive sensors are not operated in simultaneous mode
- the temporal shift for the illumination and the data of consecutive sensors corresponds to one pixel read-out cycle only, so that corresponding pixels (spectral lines) of the sensors are illuminated almost simultaneously (leading to best possible comparison results for multiplexed spectra)
- pulsed illumination is feasible due to the small temporal shift of the sensor data
- best potential for dynamic processes and differential measurements
- all active spectral sensors are operated with the same integration time

within one scan cycle
- the minimum integration time at multi-channel operation amounts to n times the minimum integration time for single channel operation (n = number of active channels)

M8.5 Circuit Description

The functions of the multiplexer subunit can be divided into an analog and a digital 8:1 multiplexer and into a sequencer logic. The digital multiplexer and the sequencer logic are realized in a 'in-system' programmable logic integrated circuit of type AMD MACH231SP.

For the automatic recognition of the configuration the subunit contains a E2PROM component (type Philips PCF8582, 256x8) connected to the I2C Bus.

(Memory addressing / Data structure tbd.)
(Customer range tbd.)

Analog Multiplexer
The analog multiplexer switches the video signal from the selected sensor channel to the output of the subunit. The function is implemented by means of the '8- Channel, low-leakage, CMOS Analog Multiplexer' MAX338 from Maxim. The input signals of the MAX338 are connected directly to the corresponding Spectra Sensor SMB connectors, without any additional circuitry. The output signal is transferred by means of an impedance converter (AD744JR) to the Front End Electronics. The address inputs of the MAX338 are controlled by the sequencer logic.

Digital Multiplexer
The digital signals StartScan, EndOfScan, and Clock are switched by the digital multiplexer. Line driver circuits of the type 74HC541 are used between the digital multiplexer and the digital connections for channels 1 through 8. The address inputs of the digital multiplexer are controlled by the sequencer logic.

Sequencer Logic
Depending on the selected mode of operation, the sequencer logic accomplishes the control of the analog and digital multiplexers.

With **sequential mode of operation**, the sequencer is inactive. The channel select control lines MUL_SEL0 ... MUL_SEL2 are forwarded directly to the (analog and digital) multiplexers as address information.

With **simultaneous mode of operation,** the status of the channel select control lines MUL_SEL0 ... MUL_SEL2 determines the number of sensors to be scanned in the next cycle. The StartOfScan signal from the Front End Electronics initiates a scanning sequence. The sequencer then executes continuously pixel cycles, addressing all sensors in their sequence in each pixel cycle (starting with the Start Channel, connecting pixel clock and video signal) and clocking them once. In each pixel cycle, the EndOfScan signal from the Start Channel is observed. If its status is active, the sequencer initiates the end of a scanning sequence (by inhibiting further data storage). A scanning sequence is successfully finished as soon as all active sensors have sent their EndOfScan. The EndOfScan signals of the active sensors have to arrive within the channel sequence, but not necessarily within the same pixel cycle.

A successfully terminated scanning sequence will result in EndOfScan pulses for each of the activated channels within the last pixel cycle, forwarded to the Front End Electronics. This reaction allows a functional check for all active channels. In case of an error (e. g. unequal pixel count of different sensors), the EndOfScan pulses are only forwarded until the first input pulse is missing.

The scanning cycles of the Spectral Sensors are overlapping, each delayed by one pixel readout time (< 5 µs, see specification of Front End Electronics.

E. g. for two activated sensors (sensor 1 and sensor 2) with 256 photo diodes each, the measurement data are forwarded to the Front End Electronics in the following sequence

pixel cycle	1:	value pixel 1 sensor 1,	value pixel 1 sensor 2
pixel cycle	2:	value pixel 2 sensor 1,	value pixel 2 sensor 2
pixel cycle	3:	value pixel 3 sensor 1,	value pixel 3 sensor 2
etc. up to:			
pixel cycle 256:		value pixel 256 sensor 1,	value pixel 256 sensor 2

The values are then stored to the FIFO memory of the interface board in this sequence.

M8.6 Jumper

JU1	Reserved (e.g. for alternative readout sequence)
JU2	Reserved

M8.7 Arrangement of Components

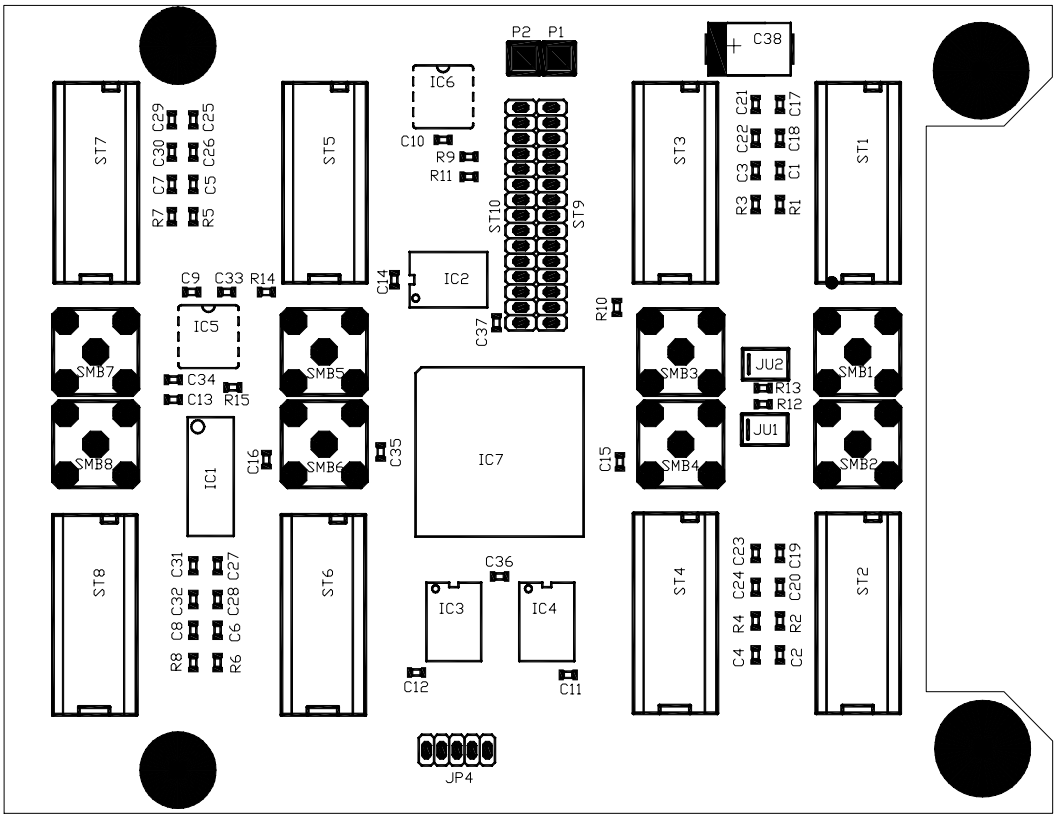

Figure M8.1: View Multiplexer MUX-8A, component side
I/O connector for Spectral Sensors and connecting elements to Front End Electronics

M8.8 Electrical Connection to Front End Electronics

Power Supply

- Spectral Sensors:
  At maximum 8 sensors (MMS / MCS / PDA S3901 ... S3904 by DZA-S3901-4)
  + 5V_analog and –5V_analog supplied by Front End Electronics
- MUX-8A:
  Analog part (MAX338): ± 12V_analog supplied by Front End Electronics,
  digital part (PLD, line drivers) direct by VCC (+5V_digital) of Front End Electronics

Electrical Connection to Front End Electronics

- in case of sandwich mount to Front End Electronics by header connectors
  2 x 15 x 1 (1.27mm pattern) ST9 and ST10

M8.9 Further Technical Data

Mechanics

circuit board dimensions 88 x 67 [mm] (same as Front End Electronics)
board may be mounted in sandwich configuration to Front End Electronics,
with PC/AT Operating Electronics for ISA or PCI Bus: mounted in Front End housing

Power supply

+5V_analog:	current of sensors only
-5V_analog:	current of sensors only
V_{CC}(+5V_digital):	typical < 110 mA
+12V_analog:	typical < 5mA
-12V_analog:	typical < 5mA

Environmental conditions

Temperature range, operating:	0°C ... 60°C (with free air convection)
Temperature range, storage:	-40°C ... +70°C
Humidity:	10% ... 90% (at 25°C), non condensing

M8.10 Pin Assignment

M8.10.1 Spectral Sensor Interface

Channel 1: ST1 and SMB1 / Channel 2: ST2 and SMB2 / Channel 3: ST3 and SMB3
Channel 4: ST1 and SMB4 / Channel 5: ST2 and SMB5 / Channel 6: ST3 and SMB6
Channel 7: ST1 and SMB7 / Channel 8: ST2 and SMB8

M8.10.1.1 Digital Control / Power - Connector ST1 ... ST8

Sensor interface type: *'Sensor_1A'*
Format: MICS10, ST1: Channel 1 ... ST8: Channel 8

Pin	Signal	Input / Output	Comment
1	n.c.		Not connected
2	C_STARTx	Output (74HC541)	Sensor StartScan
3	GND	---	Digital Ground
4	C_PHIx	Output (74HC541)	Sensor Clock
5	GND	---	Digital Ground

6	C_EOSx#	Input (Pullup to VCC = 10K ; Capacitor to GND = 220pF)	Sensor EndOf can
7	GND	---	Digital Ground
8	-5V_analog	Output (Supply from FEE)	-5V power supply for sensor
9	GND	---	Digital Ground
10	+5V_analog	Output (Supply from FEE)	+5V power supply for sensor

M8.10.1.2 Video Input– Connector SMB1 ... SMB8

Sensor interface type: *'Sensor_1A'* Format: SMB
SMB1: Channel 1 sensor video input ... SMB8: Channel 8 sensor video input
Sensor video signal on center contact

M8.10.2 Front End Interface (ST9 and ST10)

Format: 1 header connector 2 x 15 (pattern 1.27mm)
Connector (pin contacts) on solder side

Connector ST9 Pin	Signal	Comment
1	---	open
2	Reserved	Reserved signal from/to PLD, not used by MUX-8A
3	Reserved	Reserved signal from/to PLD, not used by MUX-8A
4	---	open
5	Reserved	Reserved signal from/to PLD, not used by MUX-8A
6	MX_MODE	Input, multiplexer operation mode from FEE
7	MX_CLK	Input, multiplexer main clock from FEE
8	Reserved	Reserved signal from/to PLD, not used by MUX-8A
9	START	Input, start of scan signal from FEE
10	#EOS	Output, end of scan signal to FEE
11	PHI	Input, multiplexer secondary clock from FEE
12	MX_STP	Input, delayed start of scan for latching 'multiplexer operation mode' and 'input channel select controls'
13	DGND	Digital Ground
14	AN_OUT	Output Analog Video
15	AN_GND	Analog Ground

Connector ST10 Pin	Signal	Comment
1	RES2	Reserve 2, linked to MUX-8A pin P1
2	MX_ID1	Identification Multiplexer Type signal 1, tied to Ground
3	DGND	Digital Ground, linked to MUX-8A pin P2
4	DGND	Digital Ground
5	+12V_AN	+12V_analog supply voltage input
6	VCC	VCC (+5V_digital) supply voltage input
7	MUL_SEL0	Input channel select control line 0
8	MUL_SEL1	Input channel select control line 1
9	MUL_SEL2	Input channel select control line 2
10	MX_ID0	Identification Multiplexer Type signal 0, tied to Ground
11	I2CSCL	I2C Bus line, clock signal
12	I2CSDA	I2C Bus line, data signal
13	-5V_AN	-5V_analog supply voltage input for sensors
14	+5V_AN	+5V_analog supply voltage input for sensors
15	-12V_AN	-12V_analog supply voltage input

Remark: Signal assignment of the Front End Electronics to multiplexer connector varies for different multiplexer types. Assignment is switched by the Front End Electronics depending on the multiplexers identification information.