Operating Electronics
for Spectral Sensors
and Linear Image Arrays

4 Channel Electronic Spectral Sensor Multiplexer MUX-4P

Technical Documentation

Board: **MUX-4P (06302.10)**
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M4P. Electronic Spectral Sensor Multiplexer MUX-4P

Content

M4P.1 General

In conjunction with Front End Electronics (e.g. FEE-HS or FEE-HR) the Electronic Spectral Sensor Multiplexer MUX-4P allows to operate up to 4 photo diode arrays or Spectral Sensors based on those arrays in a 'sequential' mode or a combination of two in a 'simultaneous' mode.

In mode of operation ‚sequential', the multiplexer acts like a static input switch for up to 4 Spectral Sensors 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 combination of two sensors can be read out almost concurrently with the multiplexer MUX-4P. To achieve this, the multiplexer interleaves the spectral data of the single sensors pixel for pixel. The selectable combinations are channel 1 with channel 2, channel 1 with channel 3 and channel 1 with channel 4. The size of a spectral data array is equal to the sum of the number of pixels of both activated sensors.

The multiplexer operating mode (the active sensor or the combination) is selected by software and transferred to the MUX-4P via the Front End Electronics of the Operating Electronics.

M4P.2 Concept

The passive 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 two 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-4P is called 'passive' because the electronics does not have an own scan controller. The scan controlling is done by the scan controller of the Front End Electronics.

M4P.3 Functional Characteristics

- Electronic Spectral Sensor Input Multiplexer, passive
- Inputs for 1 to 4 sensors
- Two implementation versions:
  - for FEE-HS: standard version: sensor interface type *'Sensor_1A'*
  - for FEE-HR: implementation version /HR: sensor interface type *'Sensor_5B'*
- For MMS or MCS sensors of Carl Zeiss
- For Hamamatsu diode arrays of series S3901 to S3904, operation by tec5 preamplifier DZA-S3901-4 or DZA-S3901-4 HR
- Operating modes:
  - sequential (Ch1, Ch2, Ch3, Ch4) or
  - simultaneous (Ch1&Ch2, Ch1&Ch3, Ch1&Ch4)
- Operating mode control: software programmable
- E2PROM at I2C Bus for automatic configuration recognition
- The mechanical format allows a configuration with the adapter unit ADAP_25X
- Function compatible for use with the Spectral Sensor Controller Unit MOE-C161

M4P.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 readout time for one spectra of 256 pixels is 1.4 ms at a clock frequency of 187.5 kHz (clock rate of FEE-HS). In this case, the readout time per pixel is 5.3 µs.

M4P.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

M4P.4.2 Operating Modes

For the passive multiplexer, the sequencer logic of the Front End Electronics supports the two scan modes ‚sequential' and ‚simultaneous'.
The mode and channel selection is accomplished by the PC via the I2C Bus. The Front End Electronics receives the I2C multiplexer control data from the PC and transforms the channel selection information to the discrete control signals 'MUL_SEL0' and 'MUL_SEL1' for MUX-4P. The mode information is processed in the sequencer logic of the Front End Electronics.

M4P.4.2.1 Operating Mode 'Sequential' (Scan Multiplex)

In the sequential mode of operation (scan multiplex), the multiplexer acts like an input switch for 4 sensor input channels.

Mode sequential, active channel	MultiplexerMode (FEE control signal)	MUL_SEL1	MUL_SEL0
CH1	0	0	0
CH2		0	1
CH3		1	0
CH4		1	1

All scan control signals of the Interface Electronics (StartOfScan, pixel clock) are provided to all sensors in parallel. 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 4 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

M4P.4.2.2 Operating Mode 'Simultaneous'

Whereas the active multiplexer subassemblies MUX-4A and MUX-8A use their own sequencer logic (programmable logic component) for the scan controlling in the operating mode ‚simultaneous', the passive multiplexer of type MUX-4P uses the sequencer logic function of the Front End Electronics.

This sequencer logic (of the FEE) simulates a 2-fold pixel count to the Interface Electronics. 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 both activated sensors are addressed internal in their sequence and clocked once. The scan cycle is finished as soon as both activated sensors have forwarded an EndOfScan signal to the sequencer. In this way, the measurement cycles are overlapping, with a time shift of one pixel readout cycle (approx. 5 µs at FEE-HS).

For the ‚simultaneous' mode the scan sequence and the number of active channels are defined from the PLD - design of the Front End Electronics as follows:

Mode simultaneous, scan combination	**MultiplexerMode (FEE control signal)**	**MUL_SEL1**	**MUL_SEL0**
CH1	1	0	0
CH1 & CH2		0	1
CH1 & CH3		1	0
CH1 & CH4		1	1

Characteristics:

- the sensor pair selected is read out simultaneously in each illumination cycle
- all sensors are stimulated synchronously
- a simultaneous scan acquires data from the active sensor pair (see table above), the data acquired by the other two sensors at the same time are lost
- 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 2 times the minimum integration time for single channel operation

M4P.5 Circuit Description

The multiplexer subassembly disposes of one analog and one digital 4:1 multiplexer.
For the automatic recognition of the configuration the subunit contains an 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 and the analog ground reference level from the selected sensor channel to the output of the subunit. The function is implemented by means of the 'Dual 4- Channel, low-leakage, CMOS Analog Multiplexer' MAX339 from Maxim. The input signals of the MAX339 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 (TL082) to the Front End Electronics. The address inputs of the MAX339 are controlled by the sequencer logic of the Front End Electronics.

Digital Multiplexer
The digital status signals EndOfScan and Trigger, which are supplied from the sensors on connectors ST2, ST3 or ST4, are lead through the digital multiplexer (74'153) .Synchronous with the analog multiplexer they are forwarded to the Front End Electronics.
The address inputs of the 74'153 are controlled by the sequencer logic of the Front End Electronics.

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

With '**sequential' mode of operation**, the sequencer is inactive. The multiplexer select control lines MUL_SEL0 and MUL_SEL1 are used as static address controls for the (analog and digital) multiplexers.

'**simultaneous' mode of operation**
The StartOfScan signal from the Front End Electronics initiates a scanning sequence. The sequencer of the FEE then continuously executes pixel cycles. In each cycle, first the sensor on channel 1 (main sensor) and following all the secondary sensors (channel 2, 3 and 4) are clocked once in parallel. Synchronously to the clock, the analog and digital multiplexers are switched between channel 1 and 2, 3 or 4.
In each pixel cycle, the EndOfScan signal from the multiplexer unit is observed by the FEE. If its status is active, the sequencer of the FEE initiates the end of a scanning sequence (by inhibiting further data storage). A scanning sequence is successfully finished as soon as both 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 both 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 at FEE-HS), 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.

M4P.6 Arrangement of Components

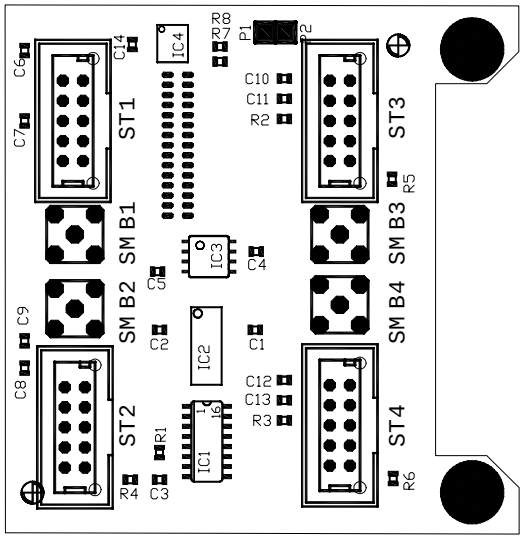

Figure M4P.1: View Multiplexer MUX-4P, component side
I/O connector for Spectral Sensors

M4P.7 Electrical Connection to Front End Electronics

Power Supply

- Spectral Sensors:
  ±5V_analog supplied by Front End Electronics for max. 4 sensors type
  MMS,
  MCS or
  PDA S3901 ... S3904 by DZA-S3901-4 or DZA-S3901-4 HR)

- MUX-4P:
  Analog part (MAX339): ± 12V_analog supplied by Front End Electronics,
  Digital part (74'153, E2PROM, OPA) 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 * 15 (1.27 mm pattern) ST5 and ST6

M4P.8 Further Technical Data

Mechanics

circuit board dimensions 66 * 67 [mm]
small board dimensions allow configuration with ADAP_25X
board may be mounted in sandwich configuration to Front End Electronics,
with PC Operating Electronics for ISA or PCI Bus: mounted in Front End housing

Power supply

+5V_analog:	current of connected sensors only
-5V_analog:	current of connected sensors only
VCC(+5V_digital):	typical < 5mA
+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
Temperature variations:	max. tbd. K / min
Humidity:	10% ... 90% (at 25°C), non condensing

M4P.9 Pin Assignment

M4P.9.1 Spectral Sensor Interface

Channel 1: ST1 and SMB1
Channel 2: ST2 and SMB2
Channel 3: ST3 and SMB3
Channel 4: ST4 and SMB4

M4P.9.1.1 Digital Control / Power - Connector ST1 ... ST4

Standard version (for FEE-HS):
Sensor interface type: *'Sensor_1A'*
Format: MICS10
Implementation version /HR:
Sensor interface type: *'Sensor_5B'*
Format: Thomas&Betts IDC-System type 501-1027ES, pin type, 10 pin

Pin	Signal	Input / Output	Comment
1	C_TRIGGER	Input (74HCT153) (Pulldown against GND = 10K)	ADC trigger signal (*)
2	C_STARTx	Output (from FEE)	Start Scan
3	C_PH2x	Output (from FEE)	Clock 2 (*)
4	C_PH1x	Output (from FEE)	Clock 1
5	C_I_RES	Output (from FEE)	Integrator reset (for DZA) (*)
6	C_EOSx#	Input (74HCT153) (Pullup against VCC = 10K)	End of Scan
7	GND	---	Digital Ground
8	-5V_analog	Output (Supply from FEE)	Sensor -5V supply
9	GND	---	Digital Ground
10	+5V_analog	Output (Supply from FEE)	Sensor +5V supply

(*): Used for HR version only, connected to ground otherwise.

M4P.9.1.2 Video Input– Connector SMB1 ... SMB4

Sensor interface type: *'Sensor_1A'* and *'Sensor_5B''*
Format: SMB

M4P.9.2 Front End Interface (ST5 and ST6*)*

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

Connector ST5 Pin	Signal	Comment
1	C2_TRIGG	Output, secondary channel, trigger signal ADC
2	C2_I_RES	Input, secondary channel, DZA integrator reset
3	C2_START	Input, secondary channel, start of scan signal
4	C2_EOS	Output, secondary channel, end of scan signal
5	C2_PH1	Input, secondary channel, clock 1
6	C2_PH2	Input, secondary channel, clock 2
7	C1_TRIGG	Output, main channel, trigger signal ADC
8	C1_I_RES	Input, main channel, DZA integrator reset
9	C1_START	Input, main channel, start of scan signal
10	C1_EOS	Output, main channel, end of scan signal
11	C1_PH1	Input, main channel, clock 1
12	C1_PH2	Input, main channel, clock 2
13	DGND	Digital Ground
14	AN_OUT	Output Analog Video
15	AN_GND	Analog Ground

Connector ST6 Pin	Signal	Comment
1	RES2	Reserve 2, linked to pin P1
2	(MX_ID1)	Open (not used)
3	DGND	Digital Ground, linked to 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 multiplexer select control line 0
8	MUL_SEL1	Input multiplexer select control line 1
9	MUL_SEL2	Input multiplexer select control line 2 (not used)
10	GND (MX_ID0)	Identification MUX type
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.