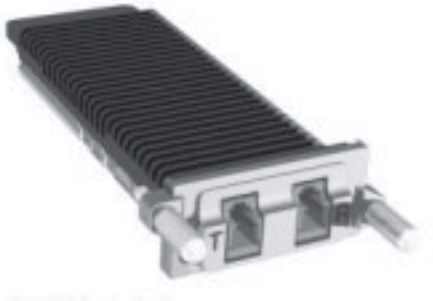
Agilent AFKC-xxxx Pluggable DWDM Transceiver for operation up to 2.7 Gb/s

Part of the Agilent METRAK family

Data Sheet



Description

The MSA compliant transceivers are high performance, compact, cost effective modules for serial optical communications at data rates up to 2.7 Gb/s. They are designed to provide SONET/SDH compliant links at 2.488 Gb/s. They are also compatible with other standard data rates such as GbE. The optical power and receiver sensitivity allow for an optical power budget of 33 dB and the dispersion performance enables a range of link distances up to 175 km. The full range of C band wavelengths is available on the ITU 100 GHz grid.

The benefits include the most compact multisourced package style available, hot pluggability and integrated power, wavelength and APD bias control. Device monitoring is provided via a 2-wire serial interface. System monitoring is via a loss of signal alarm.

The transmitter section contains a cooled DFB laser and wavelength locker and has IEC 825 Class 1M and CDRH Class 1 eye safety. The receiver section uses an APD receiver for excellent sensitivity across the whole of C band.

Connectors

Optical Connector
Simplex LC optical connector receptacles.

Electrical Connector
70 way two-row connector.

Applications

- **DWDM optical interfaces up to OC-48/STM-16 data rates with FEC**
- **Optical transport platforms**
- **Multi-service provisioning platform**
- **Optical add/drop multiplexers**
- **Optical switch and cross-connect**
- **Metro core and access networks**
- **Video Transport Systems**

Features

- **MSA Compliant (http://www.hotplugdwdm.org)**
- **Low power dissipation <2 W typical**
- **Controlled hot plugging**
- **Mountable either through the front panel or directly on the host PCB**
- **Integrated wavelength locker**
- **Data rates from 155 Mb/s to 2.7 Gb/s (no internal data re-timing)**
- **Operation across C band on the 100 GHz ITU grid**
- **Link optical power budget of 33 dB minimum**
- **Dispersion performance allows links of up to 175 km**
- **Compliant with SONET OC-48/ SDH STM-16**
- **Directly modulated, cooled, InGaAsP MQW DFB laser**
- **High sensitivity APD based receiver**
- **Automatic optical power control**
- **Automatic wavelength control**
- **Automatic internal APD bias generation and control**
- **Received power monitor**
- **AC-coupled CML compatible differential data input and output**
- **Simplex LC optical connector receptacles**
- **70 way two-row electrical connector**
- **Single +3.3 V power supply**
- **Slow or fast TX_DISABLE**

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Functional Description

A simplified schematic diagram of the transceiver is shown in Figure 1. The transmitter subassembly contains a directly modulated DFB, a wavelength locker, thermoelectric cooler (TEC), optical power monitor and thermistor. The micro-controller compares readings from the power monitor, wavelength locker and thermistor with factory-set values and corrects for any deviations over temperature and through life. Similarly, the bias voltage on the APD receiver is controlled to optimize datasheet performance.

Each transceiver can be individually addressed over the I2C bus (up to a limit of 8 per bus). The micro-controller can be interrogated and commands issued over the I2C bus (SDA and SCL lines). Alarms and Loss of Signal (LOS) are flagged by the appropriate pins (see Figure 4).

Package

The package outline, pin out (Figures 2, 3 and 4) and rail system are compliant with the multisource agreement (www.hotplugdwdm.org). The rail system for front panel or inboard mounting provides connection to chassis ground for EMI purposes.

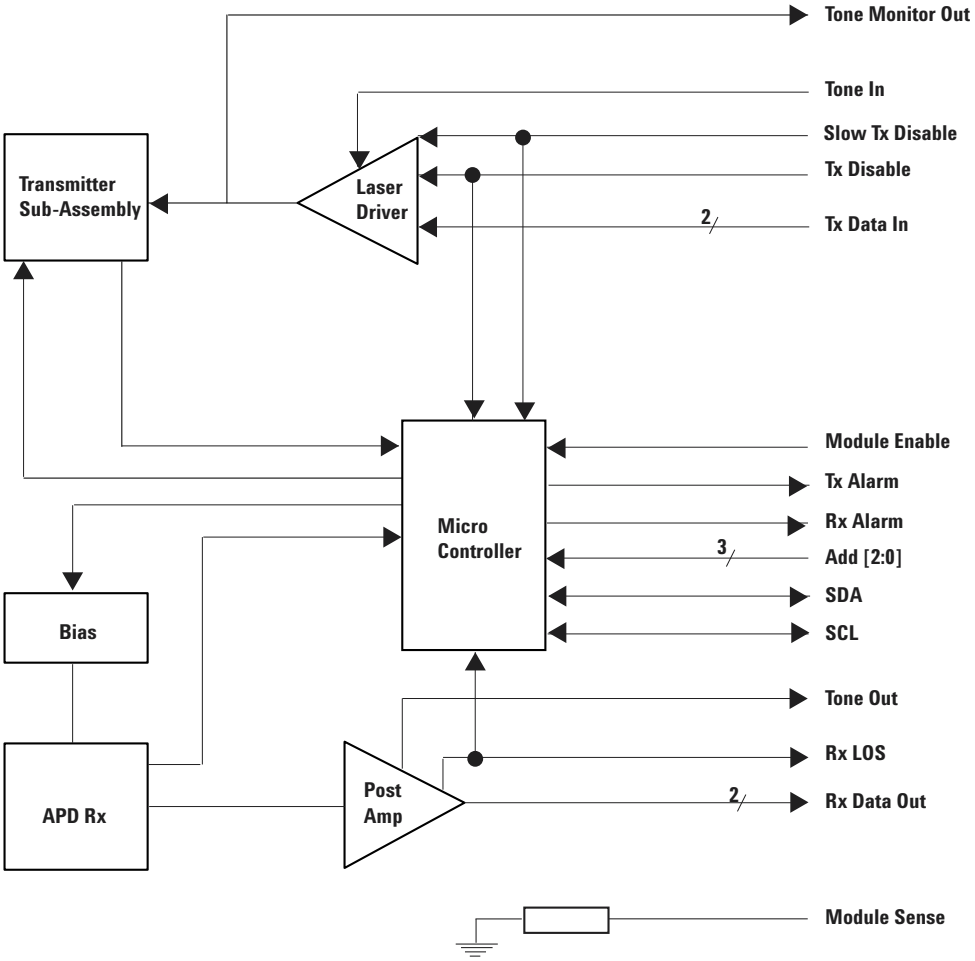

Figure 1. Simplified Transceiver Schematic

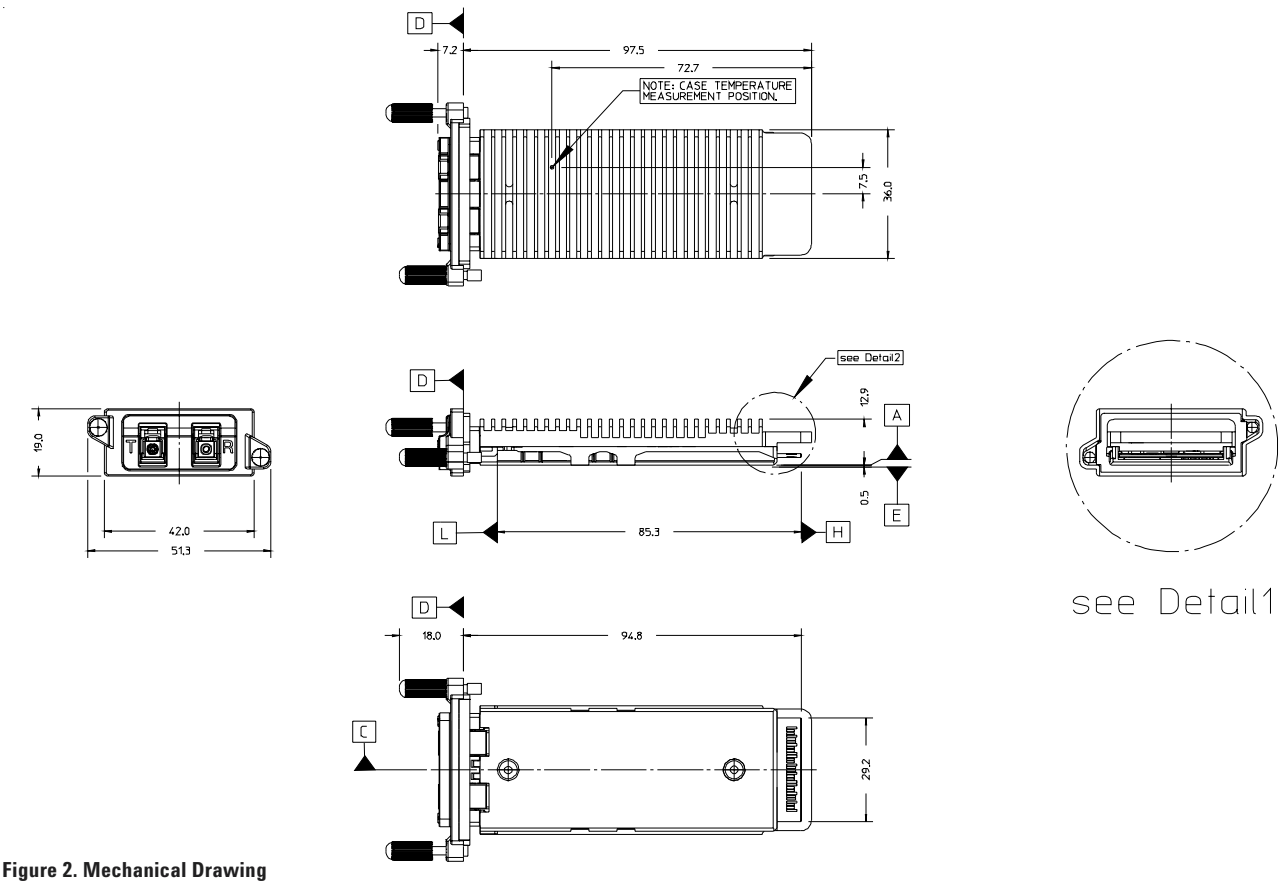

Figure 2. Mechanical Drawing

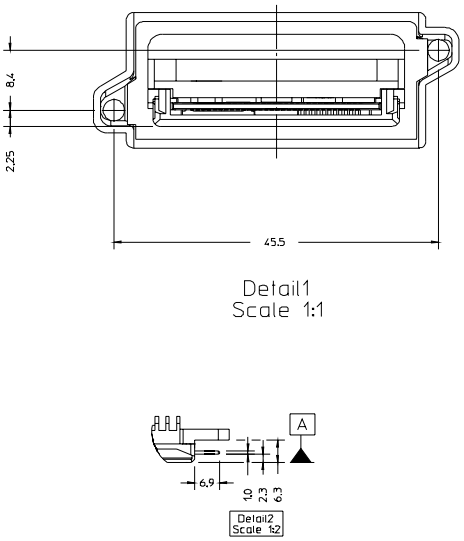

Figure 3. Detail Drawings

Definition of datums

Datum	Description Module
A	Module Base
C	Centre vertical plane of module
D	Back surface of module bezel, safety hard stop
E	Top surface of customer's PCB
H	Leading edge of module PCB
L	Vertical face of module hard stop, hard stop on rail

BOTTOM SIDE

Pin	Sequence	Description
70	1	GROUND (TX)
69	1	GROUND (TX)
68	3	NC
67	3	NC
66	1	GROUND (TX)
65	3	RESERVED
64	3	RESERVED
63	1	GROUND (TX)
62	3	RESERVED
61	3	RESERVED
60	1	GROUND (TX)
59	3	RESERVED
58	3	RESERVED
57	1	GROUND (TX)
56	3	TX DATA (-ve)
55	3	TX DATA (+ve)
54	1	GROUND (TX)
53	1	GROUND (TX)
52	1	GROUND (RX)
51	3	RESERVED
50	3	RESERVED
49	1	GROUND (RX)
48	3	RESERVED
47	3	RESERVED
46	1	GROUND (RX)
45	3	RESERVED
44	3	RESERVED
43	1	GROUND (RX)
42	3	RX DATA (-ve)
41	3	RX DATA (+ve)
40	1	GROUND (RX)
39	3	NC
38	3	NC
37	1	GROUND (RX)
36	1	GROUND (RX)

Top of the module PCB

TOP SIDE

Pin	Sequence	Description
1	2	V_{cc} (TEC)
2	2	V_{cc} (TEC)
3	2	V_{cc} (TEC)
4	1	GROUND (TEC)
5	1	GROUND (TEC)
6	1	GROUND (TEC)
7	2	V_{cc} (TX)
8	2	V_{cc} (TX)
9	1	GROUND (DIGITAL)
10	3	SDA
11	3	SCL
12	3	MODULE ENABLE
13	2	V_{cc} (DIGITAL)
14	1	GROUND (DIGITAL)
15	3	TX DISABLE
16	3	TX ALARM
17	3	TONE INPUT
18	3	TONE OUTPUT
19	3	RX ALARM
20	3	RX LOS
21	3	SLA-AD2
22	3	SLA-AD1
23	3	SLA-AD0
24	3	RESERVED
25	3	RESERVED
26	3	RESERVED
27	3	SLOW TX DISABLE
28	3	TONE MONITOR OUTPUT
29	3	MODULE SENSE
30	2	V_{cc} (RX)
31	2	V_{cc} (RX)
32	2	V_{cc} (RX BIAS)
33	1	GROUND (RX BIAS)
34	1	GROUND (RX BIAS)
35	1	GROUND (RX)

Underside of the module PCB as viewed through top of module

NOTE:
NC = NOT CONNECTED INTERNALLY
RESERVED = RESERVED FOR FUTURE EXPANSION (THESE ARE "NO USER CONNECT")

Figure 4. Electrical Pad Layout and Pin Description

Table 1. Pin Descriptions

Pin No	Pin Name	Pin Description
1:3	V_{cc} (TEC)	Supply for TEC circuit, 3.3V±5%.
4:6	Gnd (TEC)	TEC ground.
7:8	V_{cc} (Tx)	Supply for analogue Tx electronics, 3.3V±5%.
9	Gnd (Digital)	Connection to the (Digital) ground plane. Gnd (Digital) is common with Gnd (Tx) inside the module, this is ac coupled to the chassis ground with a capacitance of 100nF.[1]
10	SDA	2 wire (I2C) serial data signal. The physical layer of the interface complies with the Philips specification 9397-750-00954 'The I2C Bus Specification.' The module is designed to operate in the standard data transfer mode.
11	SCL	2 wire (I2C) serial clock signal. The physical layer of the interface complies with the Philips specification 9397-750-00954 'The I2C Bus Specification.' The module is designed to operate in the standard data transfer mode.
12	Module Enable	With the module plugged in the microcontroller is powered on by default, and always accessible. Connect Module Enable to +3.3V TTL logic high to enable the remaining on board electronics, and connect to TTL logic low to disable. For detailed operation see the truth tables in the Applications Note. LVTTL interface internally pulled down to ground via 100kΩ.
13	V_{cc} (Digital)	Supply for digital electronics, 3.3V±5%
14	Gnd (Digital)	Connection to the (Digital) ground plane. Gnd (Digital) is common with Gnd (Tx) inside the module, this is ac coupled to the chassis ground with a capacitance of 100nF.[1]
15	TX_Disable	Connect Tx Disable to +3.3V TTL logic high to disable the transmitter optical output and connect it to TTL logic low to enable. For detailed operation see the truth tables in the Applications Note. LVTTL interface internally pulled up to Vcc via 100kΩ.
16	TX_Alarm	Tx Alarm is flagged when an Alarm or Warning condition associated with the transmitter is encountered. In normal operation Tx Alarm is at TTL logic low, in a fault condition it is at +3.3V TTL logic high. For detailed operation see the truth tables in the Applications Note.
17	Tone Input	Low frequency tone injection input. Internally ac coupled, with a 10kΩ input impedance. If unused this input should be connected to ground. See the Applications Note for further description.
18	Tone Output	Low frequency tone recovery output. Internally ac coupled designed to drive a high impedance input, minimum 1kΩ. The output signal is dependent on received power and modulation depth.
19	RX_Alarm	Rx Alarm is flagged when an alarm or warning condition associated with the receiver is encountered. In normal operation Rx Alarm is at TTL logic low, in a fault condition it is at +3.3V TTL logic high. For detailed operation see the truth tables in the Applications Note.
20	RX_LOS	LOS is a loss of power warning. On a modulated signal the LOS warning is asserted and de-asserted at the power levels specified in this data sheet. When asserted LOS will be at +3.3 V TTL logic high, when de-asserted it will be at TTL logic low..
21:23	SLA-AD2 SLA-AD1 SLA-AD0	Slave address bits that define the address of the module on the I2C Bus. Configured external to the module by the customer using +3.3V TTL logic levels.
24:26	Vendor Reserved	Reserved for vendor specific functions. Do not connect
27	Slow TX_Disable	Connect Tx Disable to +3.3V TTL logic high to disable the transmitter optical output and connect it to TTL logic low to enable. For detailed operation see the truth tables in the Applications Note. LVTTL interface internally pulled down to ground via 100kΩ. Slow TX_Disable can be used to switch off the laser with the power reducing from 90% to 10% of its operational value in >150 µs and <1 ms.
28	Tone Monitor Output	The tone monitor output provides a DC voltage proportional to the laser modulation current and an AC pk-pk signal proportional to the tone current. This pin can be used to control the signal applied to the tone input and so maintain the modulation depth at the desired level.

Table 1. Pin Descriptions (continued)

Pin No	Pin Name	Pin Description
29	Module Sense	Internally pulled to ground via 1kΩ. Can be used by the customer to identify that a module has been plugged into the socket.
30:31	V_{cc} (Rx)	Supply for the receiver analogue electronics, 3.3V±5%
32	V_{cc} (Rx Bias)	Supply for the APD bias generator, 3.3V±5%.
33:34	Gnd (Rx Bias)	Connection to the (Rx Bias) ground plane. This is an independent ground plane inside the module.[1]
35:37	Gnd (Rx)	Connection to the (Rx) ground plane. This is an independent ground plane inside the module.[1]
38:39	NC	Not connected internally.
40	Gnd (Rx)	Connection to the (Rx) ground plane. This is an independent ground plane inside the module.[1]
41	Rx Data (+ve)	Received data output +Internally ac coupled data outputs. CML compatible.
42	Rx Data (-ve)	Received data output -Internally ac coupled data outputs. CML compatible.
43	Gnd (Rx)	Connection to the (Rx) ground plane. This is an independent ground plane inside the module.[1]
44:45	Reserved	Reserved for future functions, do not connect.
46	Gnd (Rx)	Connection to the (Rx) ground plane. This is an independent ground plane inside the module.[1]
47:48	Reserved	Reserved for future functions, do not connect.
49	Gnd (Rx)	Connection to the (Rx) ground plane. This is an independent ground plane inside the module.[1]
50:51	Reserved	Reserved for future functions, do not connect.
52	Gnd (Rx)	Connection to the (Rx) ground plane. This is an independent ground plane inside the module.[1]
53:54	Gnd (Tx)	Connection to the (Tx) ground plane. Gnd (Tx) is common with Gnd (Digital) inside the module, this is ac coupled to the chassis ground with a capacitance of 100nF.[1]
55	Tx data (+ve)	Transmit data + Internally ac coupled and terminated. CML compatible.
56	Tx data (-ve)	Transmit data - Internally ac coupled and terminated. CML compatible.
57	Gnd (Tx)	Connection to the (Tx) ground plane. Gnd (Tx) is common with Gnd (Digital) inside the module, this is ac coupled to the chassis ground with a capacitance of 100nF.[1]
58:59	Reserved	Reserved for future functions, do not connect.
60	Gnd (Tx)	Connection to the (Tx) ground plane. Gnd (Tx) is common with Gnd (Digital) inside the module, this is ac coupled to the chassis ground with a capacitance of 100nF.[1]
61:62	Reserved	Reserved for future functions, do not connect.
63	Gnd (Tx)	Connection to the (Tx) ground plane. Gnd (Tx) is common with Gnd (Digital) inside the module, this is ac coupled to the chassis ground with a capacitance of 100nF.[1]
64:65	Reserved	Reserved for future functions, do not connect.
66	Gnd (Tx)	Connection to the (Tx) ground plane. Gnd (Tx) is common with Gnd (Digital) inside the module, this is ac coupled to the chassis ground with a capacitance of 100nF.[1]
67:68	NC	Not connected internally.
69:70	Gnd (Tx)	Connection to the (Tx) ground plane. Gnd (Tx) is common with Gnd (Digital) inside the module, this is ac coupled to the chassis ground with a capacitance of 100nF.[1]

Note:
Refer to relevant section of Applications note for recommended filter circuits and control and monitor functions truth table.

1. By maintaining separate signal and chassis grounds inside the module the user has maximum flexibility to couple the ground planes outside the module as appropriate to their system. If signal and chassis ground are required to be kept separate then the pins attaching the rail mechanism to the PCB should not be connected to signal ground.

Absolute Maximum Ratings

Stresses in excess of the absolute maximum ratings can cause catastrophic damage to the device. Limits apply to each parameter in isolation, all other parameters having values within the recommended operating conditions. It should not be assumed that limiting values of more than one parameter can be applied to the product at the same time. Exposure to the absolute maximum ratings for extended periods can adversely affect device reliability.

Parameter	Symbol	Minimum	Typical	Maximum	Units	Notes
Storage temperature	T_S	-40		+85	°C	
Relative humidity (Non-condensing)	RH	0		85	%	
Power supply voltage	V_{CC}	-0.5		3.6	V	
Data input voltage	V_I	-0.5		V_{CC}	V	
Receiver optical input power	P_{MAX}			+8	dBm	1

Recommended Operating Conditions

Parameter	Symbol	Minimum	Typical	Maximum	Units	Notes
Case temperature	T_C	-5		+75	°C	2,3
Power supply voltage	V_{CC}	3.135	3.3	3.465	V	
Power supply noise tolerance	P_{SNT}			100	mV_{PP}	4
Slow TX + TX disable input voltage - low				0.15 V_{CC}	V	5, 6
Slow TX + TX disable input voltage - high		0.8 V_{CC}			V	5, 6
Module enable input voltage - low				0.15 V_{CC}	V	6
Module enable input voltage - high		0.8 V_{CC}			V	6

Transmitter Electrical Characteristics (Note 7)

Parameter	Symbol	Minimum	Typical	Maximum	Units	Notes
TX supply current (V_{CC} TX)	I_{CC} TX			170	mA	
TEC supply current (V_{CC} TEC)	I_{CC} TEC			550	mA	8
Digital supply current (V_{CC} DIGITAL)	I_{CC} DIGITAL			15	mA	
Power dissipation	P_{DISS}		1.1	2.3	W	9
TX Data input voltage (differential)	V_{ID}	400		1000	mV_{PP}	10
TX ALARM output voltage - low				0.25	V	6
TX ALARM output voltage - high		V_{CC} - 0.5			V	6
TX disable assert time				10	µs	11
Slow TX Disable assert time		150		1000	µs	11

Notes:

1. Duration of exposure to be less than 24 hours.
2. For details of recommended air flow and ambient temperature refer to Application Note.
3. See drawing for maximum case temperature point.
4. Between 10 Hz and 1 MHz and with required filter.
5. Laser is switched off when TX Disable is high.
6. For input current < 100 µA.
7. Over specified case temperature range, power supply voltage range at end of life @ OC-48.
8. Maximum current in steady state max case temperature. Maximum current during warm up is 850 mA.
9. Maximum power dissipation is defined at worst case end of life, which maximum dissipation for every components, steady state currents and 75C case temperature.
10. Internally ac coupled and terminated (100 Ω).
11. Disable assert time is time taken to go from 90% to 10% of operational TX optical power.

Receiver Electrical Characteristics (Note 7)

Parameter	Symbol	Minimum	Typical	Maximum	Units	Notes
RX supply current (V_{CC} RX)	I_{CC} RX			240	mA	
APD supply current (V_{CC} RX BIAS)	I_{CC} RX BIAS			70	mA	
Power dissipation	P_{DISS}		0.75	1.0	W	9
RX DATA (CML differential)	V_{DIFF}	640	800	1000	mV	12
RX DATA (CML single ended)	V_{SE}	320	400	500	mV	12
Data output Rise and fall time (20% to 80%)	T_r/T_f			150	ps	12
LOS low	LOS_D			0.25	V	13, 14
LOS high (asserted)	LOS_A	V_{CC} - 0.5			V	13, 14
LOS assert time Logic low to high	t_{ALOS}	2.3		100	us	
LOS deassert time Logic high to low	t_{DLOS}			100	us	

Transmitter Optical Characteristics (Note 7)

Parameter	Symbol	Minimum	Typical	Maximum	Units	Notes
Data rate		155		2700	Mb/s	15
Average optical output power	P_{AVG}	3	4.5	6	dBm	
Optical extinction ratio	E_R	8.2	9.0		dB	
Spectral side mode suppression ratio	SMSR	30			dB	
Relative intensity noise	RIN			-140	dB/Hz	16
Optical output eye diagram	Compliant with eye mask Telcordia GR-253-CORE and ITU-T G.957					
Central frequency	f_0		196.1-0.1 *i*		THz	17
Channel spacing	Δf		100		GHz	
Deviation from central frequency				±6	GHz	
Spectral characteristics under modulation (–20 dB line width)	$\Delta\lambda_{20}$		0.2	0.4	nm	
Jitter generation	pk to pk			70	mUI	
	RMS			7	mUI	
Dispersion penalty	D_P			2	dB	18
Back reflection sensitivity				-24	dB	19
Optical output power in 'off' state				-40	dBm	20

Notes:

12. Data outputs are internally ac coupled and require external termination at the inputs of the receiving equipment via a 100 Ω differential load.
13. LOS is LVTTL compatible. For multirate applications LOS may be detected for long "all-zeros" patterns.
14. For output current <2.5 mA,
15. Information on operation at 9 data rates below 155 Mb/s available on request.
16. Measured in the frequency range 100 MHz to 3 GHz.
17. ITU grid, *i* from 0 to 4.
18. Measured with 2^{23}-1 PRBS, 10^{-10} BER at 2.48832 Gb/s for link distances up to 110km (AFKC-xxxxD) and 175km (AFKC-xxxxE), over standard single mode fiber with maximum dispersion as defined in ITU-T G.957, Fig A.2 for G.652 fiber.
19. With no degradation of BER.
20. With TX disable asserted and/or module enable de-asserted.

Receiver Optical Characteristics (Note 7)

Parameter	Symbol	Minimum	Typical	Maximum	Units	Notes
Data rate		155		2700	Mb/s	21
Optical input power	P_R	-30		-6	dBm	22
LOS Deassert	P_D			-33	dBm	
LOS Assert	P_A	-45			dBm	
LOS Hysteresis	P_D - P_A	0.5		4	dB	
Receiver optical reflectance	R_{OR}			-27	dB	
Wavelength range		1500		1580	nm	23

Tone

Parameter	Symbol	Minimum	Typical	Maximum	Units	Notes
Input Voltage		0		2.0	V_{PP}	24
Output Voltage		0		2.5	V_{PP}	25
Modulation Frequency		50		500	kHz	26
Monitor Output		0		2.0	V	27
Tone Penalty				0.5	dB	28

Serial Interface

The physical layer of the interface complies with the Philips I2C Bus Specification. Addressing, command structure, static data, diagnostic monitoring, alarms and warnings are all MSA compliant.

Electrical Characteristics

Parameter	Symbol	Minimum	Typical	Maximum	Units	Notes
I2C interface (SCL and SDA)	V_{IL}	0		0.3 V_{CC}	V	29
	V_{IH}	0.7 V_{CC}		V_{CC}	V	29
I2C interface (SDA output)	V_{OL}	0		0.5	V	29
	V_{OH}	V_{CC} - 0.5		V_{CC}	V	29

Monitor Functions available over the Serial Interface

Parameter	Monitor	Warning	Alarm	Alarm Action
Laser temperature	Yes			
Module temperature	Yes	If low/high	If low/high	Shut down Tx and Rx
Laser bias current	Yes	If high		
Laser modulation current	Yes			
TEC current		If high		
Tx optical power	Yes		If low/high	Shut down Tx only
Rx optical power	Yes (Note 30)	If high		
APD bias voltage	Yes		If high	Shut down Rx only
LOS		Yes		
Wavelength		If outside normal operating limits	If >50 GHz from ITU frequency	Shut down Tx only
Start-up time-out		Note 31	If start time high	Shut down Tx only

Notes:

21. Operation at 2.7 Gb/s and at data rates below 155 Mb/s at reduced sensitivity. Information available on request.
22. At 2.48832 Gb/s and 10^{-10} error rate with a PRBS 2^{23}-1 input, with a TX source E_R of 8.2 dB.
23. Results up to 1610 nm available on request.
24. 1 volt pk-pk input produces approximately 12% mod depth. Mod depth is defined at the optical output as 100*(pk-pk tone /average output power).
25. Tone output voltage. Output swing is dependent on level of optical input. Under fixed optical input conditions the output variation due to mod depth is linear.
26. Modulation frequency. –3 dB bandwidth.
27. The monitor output gives a DC voltage proportional to the modulation current and an AC pk-pk signal proportional to the tone current. Eg if DC level is 1 volt and AC signal is 120 mV then the tone is 12% of the modulation current. This pin is used by the customer to control the signal applied to the tone input and thereby adjust the mod depth to the desired level.
28. For modulation depth of 6% or less, at 2.48832 Gb/s and 10^{-10} error rate with a PRBS 2^{23}-1 input..
29. 2-wire serial interfaces each require an external 4.7 k to 10 k pull up resistor to V_{CC}.
30. Accurate to within ±1.5 dB.
31. TX ALARM signal is high throughout the module's start up sequence.

Ordering Information

DWDM Transceiver

AFKC-xxxxx

Code	Link Distance (km)
D	110
E	175

Code	Frequency (THz)	Wavelength (nm)
9610	196.10	1,528.77
9600	196.00	1,529.55
9590	195.90	1,530.33
9580	195.80	1,531.12
9570	195.70	1,531.90
9560	195.60	1,532.68
9550	195.50	1,533.47
9540	195.40	1,534.25
9530	195.30	1,535.04
9520	195.20	1,535.82
9510	195.10	1,536.61
9500	195.00	1,537.40
9490	194.90	1,538.19
9480	194.80	1,538.98
9470	194.70	1,539.77
9460	194.60	1,540.56
9450	194.50	1,541.35
9440	194.40	1,542.14
9430	194.30	1,542.94
9420	194.20	1,543.73
9410	194.10	1,544.53
9400	194.00	1,545.32
9390	193.90	1,546.12
9380	193.80	1,546.92
9370	193.70	1,547.72

Code	Frequency (THz)	Wavelength (nm)
9360	193.60	1,548.51
9350	193.50	1,549.32
9340	193.40	1,550.12
9330	193.30	1,550.92
9320	193.20	1,551.72
9310	193.10	1,552.52
9300	193.00	1,553.33
9290	192.90	1,554.13
9280	192.80	1,554.94
9270	192.70	1,555.75
9260	192.60	1,556.55
9250	192.50	1,557.36
9240	192.40	1,558.17
9230	192.30	1,558.98
9220	192.20	1,559.79
9210	192.10	1,560.61
9200	192.00	1,561.42
9190	191.90	1,562.23
9180	191.80	1,563.05
9170	191.70	1,563.86
9160	191.60	1,564.68
9150	191.50	1,565.50
9140	191.40	1,566.31
9130	191.30	1,567.13
9120	191.20	1,567.95

Related Products

AFKA-0006 Evaluation accessories for AFKC-xxxxD and AFKC-xxxxE. Consists of evaluation board, cables and GUI.

www.agilent.com/ semiconductors

For product information and a complete list of distributors, please go to our web site.
For technical assistance call:
Americas/Canada: +1 (800) 235-0312 or (916) 788-6763
Europe: +49 (0) 6441 92460
China: 10800 650 0017
Hong Kong: (+65) 6756 2394
India, Australia, New Zealand: (+65) 6755 1939
Japan: (+81 3) 3335-8152(Domestic/International), or 0120-61-1280(Domestic Only)
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Taiwan: (+65) 6755 1843
Data subject to change.

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