L90 Line Differential Relay: Fiber Interface Communications Specification

EXECUTIVE SUMMARY

The maximum distances for the L90 Fiber Interfaces have been calculated using two different methods:

1. From a Power Budget determined from the Worst Case Transmitter Power and the Worst Case Receiver Sensitivity.
2. From a Power Budget determined from the Transmit Power and Receiver Sensitivity of the actual L90 communications modules (7A, 7B, 7C, and 7D).

For maximum distance the lowest loss ratio for specified fiber cable was used. Furthermore, the distance calculations assumed the following losses; 2dB loss for connections, 1 dB loss for aging, and provided a 2dB-operating margin. Therefore, Assumed Losses = 5dB.

These figures are based on the Worst Case Transmitter Power and the Worst Case Receiver Sensitivity.

Power Budget

Interface Type	Power Budget
820nm LED, Multi-mode	10dB
1300nm LED, Multi-mode	9dB
1300nm ELED, Single-mode	9dB
1300nm LASER, Single-mode	29dB

Maximum Distance

Interface Type	Maximum (km)
820nm LED, Multi-mode	1.9
1300nm LED, Multi-mode	7.2
1300nm ELED, Single-mode	11.4
1300nm LASER, Single-mode	68.5

These figures are based on Actual Transmitter Power and Actual Receiver Sensitivity at 25°C.

Power Budget

Interface Type	Power Budget
820nm LED, Multi-mode	15.6
1300nm LED, Multi-mode	13.3
1300nm ELED, Single-mode	13
1300nm LASER, Single-mode	30.52

Maximum Distance

Interface Type	Maximum (km)
820nm LED, Multi-mode	4
1300nm LED, Multi-mode	15
1300nm ELED, Single-mode	22
1300nm LASER, Single-mode	72

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L90 Fiber Specifications

Purpose:

The purpose of this report is to determine the L90 communications distance specifications for the fiber-optic modules 7A, 7B, 7C, and 7D.

Background:

Attenuation is the rate of power loss in a fiber optic system. System losses are often due to the combination of several factors such as the type of fiber, splice points, and core misalignments joined at the splice or connector. End-to-end attenuation tests can be conducted in three simple tests with an optical power meter and light source as shown in the example below.

Apparatus:

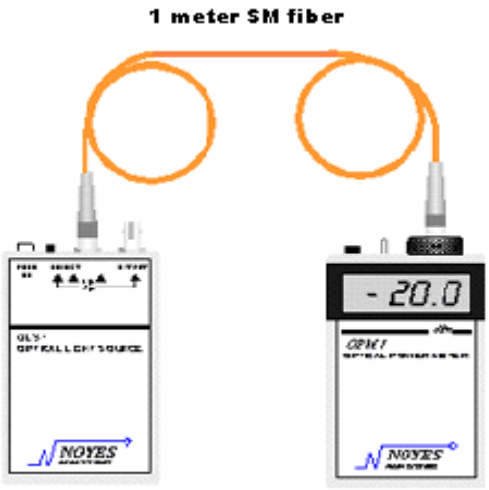
- Fiber Optic Source (850nm)
- Fiber Optic Meter
- 5 dB Attenuators
- 20dB Attenuators
- Hewlett Packard Optical Attenuator (8156A) equipped with a HP81531A Power Sensor
- single mode fiber optic cable 1 meter in length
- Single Mode Fiber Optic Cable (1 meter)
- 2 L90 UR Relays
- 2 L90 Communications Modules 7A
- 2 L90 Communications Modules 7B
- 2 L90 Communications Modules 7C
- 2 L90 Communications Modules 7D

Example of End-to-End Attentuation Test

Reference Level:

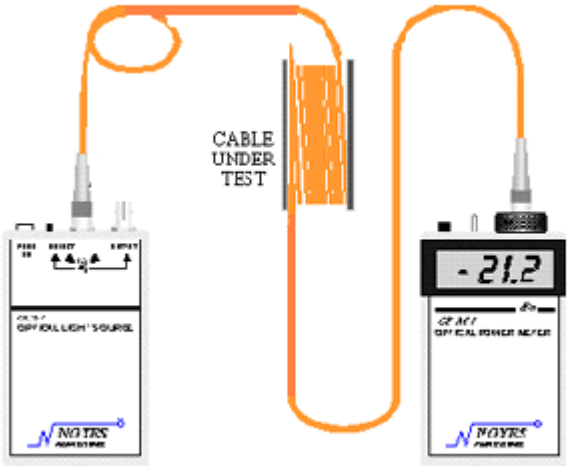
Connect the Optical Power Meter to the Optical Light Source with a single-mode fiber optic cable 1 meter in length as shown in Figure 1. Record the power level displayed on the meter, this is the reference level.

Figure 1



Measurement Level:
Insert the fiber under test as shown in Figure 2. Record the new meter reading this is the measurement level.

Figure 2



End-to-End Loss:
The difference between the reference level and the level at the power meter after the cable under test has been inserted is the loss of the cable. Example: -20dBm – (-21.2dBm) = 1.2 dB Loss.

Procedure:

Step 1 – Reference Material
Using the Hewlett Packard Designer's Catalog, reference the Worst Case Transmitter Power, Worst Case Receiver Sensitivity and the Maximum Optical Input power for the L90 Fiber Optic Communication Modules 7A, 7B, 7C, and 7D. This data is relevant for determining the maximum end-to-end loss that each interface will tolerate (Power Budget).

Step 2 - Determine Power Budget
Using the Worst Case Transmitter Power and the Worst Case Receiver Sensitivity, calculate the power budget for each of the fiber modules and record results in Table 1.

Power Budget = Worst Case Transmitter Power – Worst Case Receiver Sensitivity

Step 3 – Maximum Optical Input Power
The Maximum Optical Input Power is the maximum power that a receiver can tolerate without causing damage to the receiver photodiode. Therefore, it is extremely important and must be recorded in Table 2.

Step 4 – Maximum Distance
Calculate the maximum distance that each L90 fiber module can communicate based on the power budget calculated from the worst case transmitter power and the worst case receiver sensitivity using the Typical Loss Characteristics of Fiber Cables listed below. Record results in Table 3.

Typical Loss Characteristics of Fiber Cables

Type of Fiber Cable	Core/Clad Ratio	Loss dB/km
SM 1310	9/125	0.35 – 0.5
MM 1310	50/125µm	0.55 – 1.5
MM 1310	62.5/125µm	0.61 – 1.5
MM 850	50/125µm	2.6 – 3.5
MM 850	62.5/125µm	4

*Note: For maximum distance use lowest loss ratio for specified fiber cable. Furthermore, the distance calculations should assume the following losses: 2dB loss for connections, 1 dB loss for aging, and provide for a 2dB operating margin. Therefore, Assumed Losses = 5dB.

Maximum Distance = (Power Budget – Assumed Losses) / Lowest Loss Ratio for specified cable

Step 5 – Verify Power Budget
Verify that the L90 Fiber Modules 7A, 7B, 7C, and 7D work within the specified Power Budget. This can be accomplished by inserting Optical Attenuators into the Tx connector of each relay and connecting them back to back with a single-mode fiber optic cable 1 meter in length. The actual attenuation can be verified using the End-to-End Attenuation Test. To verify the operation of the L90 communications module, monitor the Actual Values \ Status \ Channel Tests \ Channel Status parameter of each UR and

ensure that the Channel Status displays 'O.K.', the PFLL Status displays 'O.K.', and that a Differential Trip can be operated. Record the results for each L90 Module.

Step 6 – Actual Values Power Budget
Calculate the Power Budget and Maximum Distance from the actual values obtained from each of the L90 communication modules and record the results in Table 4.

Results:

Step 1 – Reference Material

820nm LED Fiber Interface (Module 7A)

Transmitter HFBR-1414M
Receiver HFBR-2416M

Features:
- Distances up to 4 km at Signal Rates of 175 MBd
- Performance Specified with 50/125 µm, 62.5/125 µm, 100/140 µm, and 200 µm HCS Fiber

Link Performance: At Data Rates 1 – 20 MBd

Parameter	Symbol	Min.	Typ.	Max.	Unit	Conditions	Reference
Optical Power Budget with 50/125 µm fiber	OPB_{50}		7.9		dB		Note 2
Optical Power Budget with 62.5/125 µm fiber	OPD_{62}		11.7		dB		Note 2

***Notes:**
1. Typical data at T_A =25°C, V_{CC} = 5.0 Vdc, PECL serial interface.

2. Typical OPD was determined at a probability of error (BER) of 10^{-9}. Lower probabilities of error can be achieved with short fibers that have less optical loss.

LINK SELECTION GUIDE

Data Rate (MBd)	Distance (m)	Transmitter	Receiver	Fiber Size (µm)	Evaluation Kit
5	1500	HFBR-14X2	HFBR-24X2	200 HCS	N/A
5	2000	HFBR-14X4	HFBR-24X2	62.5/125	HFBR-04X0
20	2700	HFBR-14X4	HFBR-24X6	62.5/125	HFBR-0414, HFBR-0463
32	2200	HFBR-14X4	HFBR-24X6	62.5/125	HFBR-0414
55	1400	HFBR-14X4	HFBR-24X6	62.5/125	HFBR-0414
125	700	HFBR-14X4	HFBR-24X6	62.5/125	HFBR-0416
155	600	HFBR-14X4	HFBR-24X6	62.5/125	HFBR-0416
175	500	HFBR-14X4	HFBR-24X6	62.5/125	HFBR-0416

For additional information on specific links see the following individual link descriptions. Distances measured over temperature range from 0 to 70°C.

HFBR-14X4 Output Power Measured out of 1 Meter of Cable

Parameter	Symbol	Min.	Typ.[2]	Max.	Unit	Conditions		Reference
50/125 µm Fiber Cable NA = 0.2	PT50	-18.8	-15.8	-13.8	dBm peak	T_A = 25°C	I_F = 60 mA dc	Notes 5, 6, 9
		-19.8		-12.8				
		-17.3	-13.8	-11.4		T_A = 25°C	I_F = 100 mA dc	
		-18.9		-10.8				
62.5/125 µm Fiber Cable NA = 0.275	PT62	-15.0	-12.0	-10.0	dBm peak	T_A = 25°C	I_F = 60 mA dc	
		-16.0		-9.0				
		-13.5	-10.0	-7.6		T_A = 25°C	I_F = 100 mA dc	
		-15.1		-7.0				
100/140 µm Fiber Cable NA = 0.3	PT100	-9.5	-6.5	-4.5	dBm peak	T_A = 25°C	I_F = 60 mA dc	
		-10.5		-3.5				
		-8.0	-4.5	-2.1		T_A = 25°C	I_F = 100 mA dc	
		-9.6		-1.5				
200 µm HCS Fiber Cable NA = 0.37	PT200	-5.2	-3.7	+0.8	dBm peak	T_A = 25°C	I_F = 60 mA dc	
		-6.2		+1.8				
		-3.7	-1.7	+3.2		T_A = 25°C	I_F = 100 mA dc	
		-5.3		+3.8				

14X2/14X4 Dynamic Characteristics

Parameter	Symbol	Min.	Typ.[2]	Max.	Units	Conditions	Reference
Rise Time, Fall Time (10% to 90%)	t_r, t_f		4.0	6.5	nsec No Pre-bias	I_F = 60 mA Figure 12	Note 7,
Rise Time, Fall Time (10% to 90%)	t_r, t_f		3.0		nsec	I_F = 10 to 100 mA	Note 7, Figure 11
Pulse Width Distortion	PWD		0.5		nsec		Figure 11

Notes:
1. For I_{FPK} > 100 mA, the time duration should not exceed 2 ns.
2. Typical data at T_A = 25°C.
3. Thermal resistance is measured with the transmitter coupled to a connector assembly and mounted on a printed circuit board.
4. D is measured at the plane of the fiber face and defines a diameter where the optical power density is within 10 dB of the maximum.
5. P_T is measured with a large area detector at the end of 1 meter of mode stripped cable, with an ST® precision ceramic ferrule (MIL-STD-83522/13) for HFBR-1412/1414, and with an SMA 905 precision ceramic ferrule for HFBR-1402/1404.
6. When changing µW to dBm, the optical power is referenced to 1 mW (1000 µW). Optical Power P (dBm) = 10 log P (µW)/1000 µW.
7. Pre-bias is recommended if signal rate >10 MBd, see recommended drive circuit in Figure 11.
8. Pins 2, 6 and 7 are welded to the anode header connection to minimize the thermal resistance from junction to ambient. To further reduce the thermal resistance, the anode trace should be made as large as is consistent with good RF circuit design.
9. Fiber NA is measured at the end of 2 meters of mode stripped fiber, using the far-field pattern. NA is defined as the sine of the half angle,determined at 5% of the peak intensity point. When using other manufacturer's fiber cable, results will vary due to differing NA values and specification methods.

Electrical/Optical Characteristics -40°C to +85°C; 4.75 V ≤ Supply Voltage ≤ 5.25 V, R_{LOAD} = 511 Ω, Fiber sizes with core diameter ≤ 100 µm, and N.A. ≤ -0.35 unless otherwise specified

Parameter	Symbol	Min.	Typ.[2]	Max.	Units	Conditions	Reference
Responsivity	R_P	5.3	7	9.6	mV/µW	T_A= 25°C @ 820 nm, 50 MHz	Note 3, 4 Figure 16
		4.5		11.5	mV/µW	@ 820 nm, 50 MHz	
RMS Output Noise Voltage	V_{NO}		0.40	0.59	mV	Bandwidth Filtered @ 75 MHz P_R = 0 µW	Note 5
				0.70	mV	Unfiltered Bandwidth P_R = 0 µW	Figure 13
Equivalent Input Optical Noise Power (RMS)	P_N		-43.0	-41.4	dBm	Bandwidth Filtered @ 75 MHz	
			0.050	0.065	µW		
Optical Input Power (Overdrive)	P_R			-7.6	dBm pk	T_A = 25°C	Figure 14 Note 6
				175	µW pk		
				-8.2	dBm pk		
				150	µW pk		
Output Impedance	Z_o		30		Ω	Test Frequency = 50 MHz	
dc Output Voltage	$V_{o\,dc}$	-4.2	-3.1	-2.4	V	P_R = 0 µW	
Power Supply Current	I_{EE}		9	15	mA	R_{LOAD} = 510 Ω	
Equivalent N.A.	NA		0.35				
Equivalent Diameter	D		324		µm		Note 7

Ethernet 20 MBd Link (HFBR-14X4/24X6)

(refer to Application Note 1038 for details)

Typical Link Performance

Parameter	Symbol	Typ.[1,2]	Units	Conditions
Receiver Sensitivity		-34.4	dBm average	20 MBd D2D2 Hexadecimal Data 2 km 62.5/125 µm fiber
Link Jitter		7.56	ns pk-pk	ECL Out Receiver
		7.03	ns pk-pk	TTL Out Receiver
Transmitter Jitter		0.763	ns pk-pk	20 MBd D2D2 Hexadecimal Data
Optical Power	P_T	-15.2	dBm average	20 MBd D2D2 Hexadecimal Data Peak $I_{F,ON}$ = 60 mA
LED rise time	t_r	1.30	ns	1 MHz Square Wave Input
LED fall time	t_f	3.08	ns	
Mean difference	$\lvert t_r - t_f \rvert$	1.77	ns	
Bit Error Rate	BER	10^{-10}		
Output Eye Opening		36.7	ns	At AUI Receiver Output
Data Format 50% Duty Factor		20	MBd	

Notes:
1. Typical data at T_A = 25°C, V_{CC} = 5.0 V dc.
2. Typical performance of circuits shown in Figure 1 and Figure 3 of AN-1038 (see applications support section).

Token Ring 32 MBd Link (HFBR-14X4/24X6)

(refer to Application Note 1065 for details)

Typical Link Performance

Parameter	Symbol	Typ.[1,2]	Units	Conditions
Receiver Sensitivity		-34.1	dBm average	32 MBd D2D2 Hexadecimal Data 2 km 62.5/125 µm fiber
Link Jitter		6.91	ns pk-pk	ECL Out Receiver
		5.52	ns pk-pk	TTL Out Receiver
Transmitter Jitter		0.823	ns pk-pk	32 MBd D2D2 Hexadecimal Data
Optical Power Logic Level "0"	$P_{T\,ON}$	-12.2	dBm peak	Transmitter TTL in $I_{F\,ON}$ = 60 mA, $I_{F\,OFF}$ = 1 mA
Optical Power Logic Level "1"	$P_{T\,OFF}$	-82.2		
LED Rise Time	t_r	1.3	nsec	1 MHz Square Wave Input
LED Fall Time	t_f	3.08	nsec	
Mean Difference	$\lvert t_r - t_f \rvert$	1.77	nsec	
Bit Error Rate	BER	10^{-10}		
Data Format 50% Duty Factor		32	MBd	

Therefore:

Worst case transmitter power = -20 dBm
Worst case receiver sensitivity = -30 dBm
Max. Optical Input Power = -7.6 dBm

Power Budget = -20dBm – (-30dBm)
= 10dB

1300nm LED Fiber Interface (Module 7B)

Transmitter HFBR-1312T
Receiver HFBR-2316T

Features:

- Distances up to 2 km at Signal Rates of 125 MBd and 5 km at 32 MBd

HFBR-1312T Transmitter Output Optical Power and Dynamic Characteristics

Parameter	Symbol	Min.	Typ.[1]	Max.	Unit	Condition		Ref.
						T_A	$I_{F,peak}$	
Peak Power 62.5/125 µm NA = 0.275	P_{T62}	-16.0	-14.0	-12.5	dBm	25°C	75 mA	Notes 3, 4, 5 Fig. 2
		-17.5		-11.5		0-70°C	75 mA	
		-15.5	-13.5	-12.0		25°C	100 mA	
		-17.0		-11.0		0-70°C	100 mA	
Peak Power 50/125 µm NA = 0.20	P_{T50}	-19.5	-17.0	-14.5	dBm	25°C	75 mA	Notes 3, 4, 5 Fig. 2
		-21.0		-13.5		0-70°C	75 mA	
		-19.0	-16.5	-14.0		25°C	100 mA	
		-20.5		-13.0		0-70°C	100 mA	
Optical Overshoot	OS		5	10	%	0-70°C	75 mA	Note 6 Fig. 3
Rise Time	t_r		1.8	4.0	ns	0-70°C	75 mA	Note 7 Fig. 3
Fall Time	t_f		2.2	4.0	ns	0-70°C	75 mA	Note 7 Fig. 3

HFBR-2316T Receiver Electrical/Optical and Dynamic Characteristics

0 to 70°C; 4.75 V < V_{CC} - V_{EE} < 5.25 V; power supply must be filtered (see note 2).

Parameter	Symbol	Min.	Typ.[3]	Max.	Unit	Condition	Ref.
Responsitivity	R_P	6.5	13	19	mV/µW	λ_p = 1300 nm, 50 MHz	Note 4 Fig. 1, 5
RMS Output Noise Voltage	V_{NO}		0.4	0.59	mV_{RMS}	100 MHz bandwidth, P_R = 0 µW	Note 5 Fig. 2
				1.0	mV_{RMS}	Unfiltered Bandwidth P_R = 0 µW	
Equivalent Optical Noise Input Power (RMS)	$P_{N,RMS}$		-45	-41.5	dBm	@ 100 MHz, P_R = 0 µW	Note 5
			0.032	0.071	µW		
Peak Input Optical Power	P_R			-11.0	dBm	50 MHz, 1 ns PWD	Note 6
				80	µW		Fig. 3
Output Resistance	R_O		30		Ohm	f = 50 MHz	
DC Output Voltage	$V_{O,DC}$	0.8	1.8	2.6	V	V_{CC} = 5 V, V_{EE} = 0 V P_R = 0 µW	
Supply Current	I_{CC}		9	15	mA	R_{LOAD} = ∞	
Electrical Bandwidth	BW_E	75	125		MHz	-3 dB electrical	Note 7
Bandwidth * Rise Time Product			0.41		Hz *s		
Electrical Rise, Fall Times, 10-90%	t_r,t_f		3.3	5.3	ns	P_R = -15 dBm peak, @ 50 MHz	Note 8 Fig. 4
Pulse-Width Distortion	PWD		0.4	1.0	ns	P_R = -11 dBm, peak	Note 6,9 Fig. 3
Overshoot			2		%	P_R = -15 dBm, peak	Note 10

Therefore:

Worst case transmitter power = -21 dBm
Worst case receiver sensitivity = -30 dBm
Max. Optical Input Power = -11.0 dBm

Power Budget = -21dBm – (-30dBm)
= 9dB

1300nm ELED Fiber Interface (Module 7C)

Transmitter HFBR-1315M
The HFBR-1315M single-mode fiber-optic transmitter contains a 1300nm edge-emitting LED (E-LED) capable of launching optical power into single-mode fiber.

Receiver HFBR-2315M
The HFBR-2315M receiver contains an InGaAs PIN photodiode and a low noise transimpedance preamplifier operating in the 1300nm-wavelength region. The HFBR-2315M receives an optical signal and converts it to an analog voltage. The buffered output is an emitter-follower, with a frequency response from dc to typically 125 MHz.

Features:
- Distances up to 14 km at Signal Rates of 20 MBd
- Performance Specified with Single-Mode Fiber Cables

Link Performance: At Data Rates 1-20 MBd

Parameter	Symbol	Min.	Typ.	Max.	Unit	Conditions	Reference
Optical Power Budget with Single-Mode Fiber Cables	OPB	9	18		dB	0 to 70°C	Note 1
Link Distance with Single-Mode Fiber Cables	ℓ	14			km	0 to 70°C	Note 2

Notes:
1. Optical Power Budget applies to HFBR-1315TM/1315M and HFBR-2315T/2315M in the recommended application circuit (Figures 1 and 2). Worst case transmitter coupled power (P_T) is -27 dBm peak, -30 dBm average. Worst case receiver sensitivity is -36 dBm peak, -39 dBm average. Refer to Application Note 1082 for details.
2. Link distance is based on fiber with 0.5 dB/km attenuation, and assumes 1 dB for loss of in-line splices or connectors, and 1 dB margin for LED aging: (9 dB OPB - 1 dB in-line splice loss - 1 dB aging margin)/(0.5 dB/km) = 14 km.

HFBR-1315TM/1315M - Transmitter Optical Output Power and Dynamic Characteristics

Parameter	Symbol	Min.	Typ.[1]	Max.	Unit	Conditions		Reference
						T_A	$I_{F,peak}$	
Peak Power	P_T	-23	-21	-17	dBm	25°C	100 mA	Note 2
Single-mode		-27		-15		0-70°C	100 mA	Figure 4
Rise, Fall Time (10% to 90%)	t_r, t_f			4.5	ns	0-70°C	100 mA, No Pre-bias	Note 4 Figure 5
Rise, Fall Time (10% to 90%)	t_r, t_f		2.6 1.6		ns	0-70°C	100 mA, With Pre-bias	Note 4 Figure 1

Notes:
1. Typical data are at T_A = 25°C.
2. Optical power is measured with a large area detector at the end of 1 meter of single-mode cable, with an ST* precision ceramic ferrule (MIL-STD-83522/13), which approximates a standard test connector.
3. When changing from μW to dBm, the optical power is referenced to 1 mW (1000 μW). Optical power P(dBm) = 10*log[P(μW)/1000μW].
4. Optical rise and fall times are measured from 10% to 90% with single-mode fiber. The "No Pre-bias" response time is measured in the recommended test circuit (50 ohm load, Figure 5) at 25 MHz, 50% duty cycle. The response time "With Pre-bias" is measured in the recommended application circuit (Figure 1).

HFBR-2315T/2315M - Electrical/Optical and Dynamic Characteristics

(T_A = 0°C to 70°C; 4.75 V < (V_{CC} - V_{EE}) < 5.25 V; power supply must be filtered per note 2)

Parameter	Symbol	Min.	Typ.[3]	Max.	Unit	Condition	Reference
Responsivity, Single-Mode Fiber	R_P	8.5	17	24	mV/μW	λ_p = 1300 nm, 50 MHz	Note 4, Figures 6, 10
RMS Output Noise Voltage	V_{NO}		0.4	0.59	mV_{RMS}	@100 MHz, P_R = 0 mW	Note 5 Figure 7
				1.0	mV_{RMS}	Unfiltered Bandwidth P_R = 0 mW	
Equivalent Optical Noise Input Power (RMS)	$P_{N,RMS}$		-45	-41.5	dBm	@100 MHz, P_R = 0 mW	Note 5
			0.032	0.071	μW		
Peak Input Optical Power, Single-Mode	P_R			-14	dBm	50 MHz, 1 ns PWD	Note 6 Figure 8
				40	μW		
Output Impedance	Z_O		30		Ω	f = 50 MHz	
DC Output Voltage	$V_{O,DC}$	0.8	1.8	2.6	V	V_{CC} = 5 V, V_{EE} = 0 V P_R = 0 mW	
Supply Current	I_{CC}		9	15	mA	R_{LOAD} = ∞	
Electrical Bandwidth	BW_E	75	125		MHz	-3 dB electrical	Note 7
Bandwidth * Rise Time			0.41		Hz * s		Note 8
Electrical Rise, Fall Times, 10-90%	$t_{r,f}$		3.3	5.3	ns	P_R = -21 dBm Peak, @ 50 MHz	Note 9 Figure 9
Pulse-Width Distortion	PWD		0.4	1.0	ns	P_R = -14 dBm, Peak, Single-Mode Fiber	Note 10 Figure 8
Overshoot			2		%	P_R = -21 dBm, Peak	Note 11

Therefore:

Worst case transmitter power = -21 dBm
Worst case receiver sensitivity = -30 dBm
Max.Optical Input Power = -14 dBm

Power Budget = -21dBm – (-30dBm)
= 9dB

1300nm LASER Fiber Interface (Module 7D)

Transmitter LST3921
Receiver HFBR-2315T

Features:

Performance Specifications (Continued)

Parameter	Symbol	Test Condition	LST2525 LST3521 HFCT-3002A		LST2825 LST3821 HFCT-3012A		Unit
			Min.	Max.	Min.	Max.	
MONITOR PHOTODIODE		Tc = +25°C Vr = 5 V, Po = Rated Power					
Photocurrent	Im		200	1000	200	1000	µA
Dark current	Id	Po = 0 µW		20		20	nA
Capacitance - LST	C	1 MHz		10		10	pF
- HFCT				20		20	pF
Tracking Error	ΔR	Im = Im (Po, +25°C) Tc = -40°C to +85°C		±1		±1	dB
Rise and fall time	tr	10 - 90%, Ith to Po		2		2	ns

Fiber Pigtail

Parameter	Minimum	Maximum	Unit
Fiber Pigtail Length	1000		mm
Spot Size (Mode Radius)	4.5	5.5	µm
Cladding Diameter	122	128	µm
Core/Cladding Concentricity		1	µm
Secondary Jacket Diameter	0.8	1	mm
Effective Cutoff Wavelength	1150	1240	nm

Reliability

Parameter	Condition	Minimum	Maximum	Unit
Median Life	50% inc. in total drive current, Tc = +25°C	2 x 10^5		hours

Performance Specifications

Parameter	Symbol	Test Condition	LST2525 LST3521 HFCT-3002A		LST2825 LST3821 HFCT-3012A		Unit
			Min.	Max.	Min.	Max.	
LASER		CW, Tc = -40°C to +85°C, Po as noted below unless otherwise stated					
Rated optical power	Po	Tc = ranges specified above, CW	0.2		1		mW
Threshold current	Ith	Tc = +25°C	3.5	10	3.5	10	mA
Threshold current	Ith		1.5	30	1.5	30	mA
Coupled Power in "Off" state	Pth	If = Ith - 2 mA		12		12	µW
Slope efficiency	η	Tc = +25°C	10	16	50	100	µW/mA
Drive current above Ith, for Im = Im (Po, +25°C)	Id	Tc = +25°C	12.5	20	10	20	mA
		Tc = -40°C to +85°C	10	33.3	7.5	33.3	mA
Forward voltage - LST - HFCT	Vf			1.6		1.6	V
				3.0		3.0	V
Centre wavelength	λ	Tc = +25°C	1286	1336	1286	1336	nm
		Tc = -40°C to +85°C	1260	1360	1260	1360	nm
Wavelength/temperature coefficient	Δλ/ΔT			0.4		0.4	nm/°C
Spectral width	σ	One sigma, RMS		2.5		2.5	nm
Rise and fall time	τ	10 - 90%, Ith to Po		380		380	ps

Therefore:

Worst case transmitter power = -1 dBm
Worst case receiver sensitivity = -30 dBm
Max. Optical Input Power = -14 dBm

Power Budget = -1dBm – (-30dBm)
= 29dB

Step 2 - Determine Power Budget

Table 1

Power Budget

Interface Type	Power Budget
820nm LED, Multi-mode	10dB
1300nm LED, Multi-mode	9dB
1300nm ELED, Single-mode	9dB
1300nm LASER, Single-mode	29dB

*Note: These Power Budgets are calculated from the manufacturers worst-case transmitter power and worst case receiver sensitivity.

Step 3 – Maximum Optical Input Power

Table 2

Maximum Optical Input Power

Interface Type	Max. Optical Input Power
820nm LED, Multi-mode	-7.6dBm
1300nm LED, Multi-mode	-11dBm
1300nm ELED, Single-mode	-14dBm
1300nm LASER, Single-mode	-14dBm

Step 4 – Maximum Distance

Table 3

Maximum Distance

Interface Type	Maximum (km)
820nm LED, Multi-mode	1.9
1300nm LED, Multi-mode	7.2
1300nm ELED, Single-mode	11.4
1300nm LASER, Single-mode	68.5

*Note: For maximum distance use lowest loss ratio for specified fiber cable. Furthermore, the distance calculations should assume the following losses; 2dB loss for connections, 1 dB loss for aging, and provide for a 2dB-operating margin. Therefore, Assumed Losses = 5dB.

Step 5 – Verify Power Budget

820nm LED Fiber Interface (Module 7A)

UR Reference Level - 820nm LED Fiber Interface:
Connected the Optical Power Meter to the Tx connector on the UR using a 1-meter single mode fiber strand and measured –15.1dBm.

Attenuation Test

Reference Level (dBm)	Measurement Level (dBm)	End-to-End Loss (dB)	Channel Status	PFLL Status
-15.1	-17.8	2.7	O.K.	O.K.
-15.1	-21.3	6.2	O.K.	O.K.
-15.1	-21.8	6.7	O.K.	O.K.
-15.1	-24.4	9.3	O.K.	O.K.
-15.1	-25.6	10.5	O.K.	O.K.
-15.1	-27.2	12.1	O.K.	O.K.
-15.1	-30.7	15.6	O.K.	O.K.

1300nm LED Fiber Interface (Module 7B)

UR Reference Level - 1300nm LED Fiber Interface:

Connected the Optical Power Meter to the Tx connector on the UR using a 1-meter single mode fiber strand and measured –18.dBm.

Attenuation Test

Reference Level (dBm)	Measurement Level (dBm)	End-to-End Loss (dB)	Channel Status	PFLL Status
-18	-19.1	1.1	O.K.	O.K.
-18	-20.1	2.1	O.K.	O.K.
-18	-28.6	10.6	O.K.	O.K.
-18	-29.2	11.2	O.K.	O.K.
-18	-31.3	13.3	O.K.	O.K.

1300nm ELED Fiber Interface (Module 7C)

UR Reference Level – 1300nm ELED Fiber Interface:

Connected the Optical Power Meter to the Tx connector on the UR using a 1-meter single mode fiber strand and measured –17.1dBm.

Attenuation Test

Reference Level (dBm)	Measurement Level (dBm)	End-to-End Loss (dB)	Channel Status	PFLL Status
-17.1	-20.2	3.1	O.K.	O.K.
-17.1	-25.4	8.3	O.K.	O.K.
-17.1	-27.6	10.5	O.K.	O.K.
-17.1	-30.1	13	O.K.	O.K.

1300nm LASER Fiber Interface (Module 7D)

UR Reference Level – 1300nm LASER Fiber Interface:

Connected the Optical Power Meter to the Tx connector on the UR using a 1-meter single mode fiber strand and measured –0.67dBm.

Attenuation Test

Reference Level (dBm)	Measurement Level (dBm)	End-to-End Loss (dB)	Channel Status	PFLL Status
-0.67	-18.70	18.03	O.K.	O.K.
-0.67	-23.74	23.07	O.K.	O.K.
-0.67	-29.09	28.42	O.K.	O.K.
-0.67	-30.39	29.72	O.K.	O.K.
-0.67	-30.65	29.98	O.K.	O.K.
-0.67	-30.79	30.12	O.K.	O.K.
-0.67	-31.19	30.52	O.K.	O.K.

Step 6 - Actual Values Power Budget

Table 4

Power Budget

Interface Type	Power Budget
820nm LED, Multi-mode	15.6
1300nm LED, Multi-mode	13.3
1300nm ELED, Single-mode	13
1300nm LASER, Single-mode	30.52

*Note: These Power Budgets are calculated from actual transmitter power and actual receiver sensitivity.

Maximum Distance

Interface Type	Maximum (km)
820nm LED, Multi-mode	4
1300nm LED, Multi-mode	15
1300nm ELED, Single-mode	22
1300nm LASER, Single-mode	72

*Note: For maximum distance use lowest loss ratio for specified fiber cable. Furthermore, the distance calculations should assume the following losses; 2dB loss for connections, 1 dB loss for aging, and provide for a 2dB-operating margin. Therefore, Assumed Losses = 5dB.

Conclusion:

These figures are based on the Worst Case Transmitter Power and the Worst Case Receiver Sensitivity.

Power Budget

Interface Type	Power Budget
820nm LED, Multi-mode	10dB
1300nm LED, Multi-mode	9dB
1300nm ELED, Single-mode	9dB
1300nm LASER, Single-mode	29dB

*Note: These Power Budgets are calculated from the manufacturers worst-case transmitter power and worst case receiver sensitivity.

Maximum Optical Input Power

Interface Type	Max. Optical Input Power
820nm LED, Multi-mode	-7.6dBm
1300nm LED, Multi-mode	-11dBm
1300nm ELED, Single-mode	-14dBm
1300nm LASER, Single-mode	-14dBm

Typical Loss Characteristics of Fiber Cables

Type of Fiber Cable	Core/Clad Ratio	Loss dB/km
SM 1310	9/125	0.35 – 0.5
MM 1310	50/125µm	0.55 – 1.5
MM 1310	62.5/125µm	0.61 – 1.5
MM 850	50/125µm	2.6 – 3.5
MM 850	62.5/125µm	4

Maximum Distance

Interface Type	Maximum (km)
820nm LED, Multi-mode	1.9
1300nm LED, Multi-mode	7.2
1300nm ELED, Single-mode	11.4
1300nm LASER, Single-mode	68.5

*Note: For maximum distance use lowest loss ratio for specified fiber cable. Furthermore, the distance calculations should assume the following losses; 2dB loss for connections, 1 dB loss for aging, and provide for a 2dB-operating margin. Therefore, Assumed Losses = 5dB.

These figures are based on Actual Transmitter Power and Actual Receiver Sensitivity.

*Note: Tests were performed in a controlled environment at room temperature.

Power Budget

Interface Type	Power Budget
820nm LED, Multi-mode	15.6
1300nm LED, Multi-mode	13.3
1300nm ELED, Single-mode	13
1300nm LASER, Single-mode	30.52

*Note: These Power Budgets are based on Actual Transmitter Power and Actual Receiver Sensitivity.

Maximum Optical Input Power

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MM 850	62.5/125µm	4

Maximum Distance

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820nm LED, Multi-mode	4
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*Note: For maximum distance use lowest loss ratio for specified fiber cable. Furthermore, the distance calculations should assume the following losses; 2dB loss for connections, 1 dB loss for aging, and provide for a 2dB-operating margin. Therefore, Assumed Losses = 5dB.

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