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RF PHOTONIC LINK TEST BED

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AIR FORCE RESEARCH LABORATORY
SENSORS DIRECTORATE
ROME RESEARCH SITE
ROME, NEW YORK

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13. ABSTRACT ***(Maximum 200 Words)***

Described is a modular photonic RF link test bed integrated with the C-band radar operated by the Air Force Research Laboratory Sensors Directorate's Radar Technology Branch (SNRT). This flexible, multi-channel, test bed allows in-situ testing and evaluation of commercial and developmental photonic components in a convenient, yet realistic environment for their intended application, air and spaceborne RF sensing. This report documents the design and construction of a commercial off the shelf technology (COTS) based RF link transmitter and receiver, as well as the installation and testing of the multi-channel fiber optic link within the C-band radar. Performance of the COTS based link is reported and compared to requirements of the C-band radar for supporting typical experiments. A section on proposed future work is also presented.

14. SUBJECT TERMS

RF photonic link, analog photonic link, fiber optic link, photonic test bed, C-band radar

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1.0 Introduction

This is an interim progress report for the in-house RF link demonstration and test-bed which is part of the RF Links program.

The purpose of this effort is to design, build and test a modular photonic RF link test-bed for use in a working C-band radar set operated by the Air Force Research Laboratory Sensors Directorate's Radar Technology Branch (SNRT). This test-bed is to consist of a five-channel array of RF Links which will allow flexible in-situ testing of commercial and developmental components for high-performance analog fiber optic links. Inserting this test-bed into an existing radar set also provides insight from the user as to how these components will affect the overall operation of the radar set and provide inputs for future RF link designs.

To date, a single-channel link has been designed, built and tested, and the fiber optic cable has been installed in the radar facility.

This document begins with background information on the design and construction of the RF Link transmitter and receiver, as well as the installation and testing of the fiber optic cable in the building housing the radar set. Next, test results are presented, along with a comparison with the stated requirements for use in an operational radar set. Finally, a look at the work still needed is presented.

2.0 Program Objectives

The principal purpose of this effort is to insert a modular RF photonic test-bed into an operational radar set to enable testing and evaluation of commercial and developmental photonic link components in as realistic a representation of an operational environment as possible. We chose to insert this test-bed into SNRT's C-band radar system for several reasons. First, it is conveniently located at the Rome Research Site, near the Air Force Research Laboratory's Photonics Center (SNDP). Next, because it is used for waveform diversity and GMTI experiments, it offers fairly complex real-world signals. Finally, when this test-bed is operational, it will also benefit SNRT personnel. The test-bed will replace two sets of RF amplifiers and 425 ft of lossy coaxial cables. It will also allow more of the radar set's controls and electronics to be located in or near the control room. This will allow more flexibility for SNRT to perform their experimental work with the radar set.

SNRT personnel have stated that the performance goals for a link inserted into the C-band radar are a noise figure (NF) of 3-6 dB and a spur-free dynamic range (SFDR) of not less than 75 dB in a 20 MHz bandwidth. Since SFDR of a photonic link is typically specified in a 1-Hz bandwidth, the dynamic range requirement becomes 123.67 $dB/Hz^{2/3}$. Since this link is intended to be used in an experimental land-based radar set, size was not constrained; however, an effort was made to minimize the size of the transmitter and receiver boxes to the extent possible while still maintaining modularity.

3.0 Design Approach

Having set the program goals at a NF of 3-6 dB and a SFDR of 123.67 $dB/Hz^{2/3}$, the next step was to design the link. Although an analog photonic link can be directly-modulated, where the current to a laser is modulated with an RF signal, or externally modulated, where the continuous laser output is modulated in an external electro-optic modulator, we chose an externally-modulated link. A directly-modulated link usually has a frequency range below 10 GHz, unlike externally-modulated links, for which commercial modulators are available that have a bandwidth of over 25 GHz. However, to allow comparisons, we looked at the performance of two other RF links, one directly-modulated commercially available link and one externally-modulated link developed under contract by Uniphase Telecommunications Products. We describe the results of this testing in Appendix 3, since this will allow a comparison to our link.

A generic externally-modulated link, referred to here as simply an RF link, is shown in figure 1. This link consists of a continuous laser source, a Mach-Zender modulator which amplitude-modulates the laser light with the incoming RF signal, some length of optical transmission fiber, and a photodetector which recovers the original RF signal, as well as any matching circuitry in the input and output. The link may also include a low-noise amplifier at the input and a post-amplifier.

Ideally, the RF link would be transparent to the RF system, with no distortions of the RF signal between the input and output. This however is difficult to achieve for a practical RF link. The components of the link may distort the signal in some noticeable way. The laser may have random variations in its intensity, which is called relative intensity noise, or RIN. The Mach-Zender modulator has the raised-cosine transfer function

$$T(V) = \frac{T_0}{2} \cdot \left(1 + \cos\left(\pi \cdot \frac{V}{V_\pi} \right) \right)$$

where T_0 is the maximum transmission and V_π is the input voltage to the modulator required to minimize the light output of the modulator [5]. As can be deduced from the above equation, biasing the modulator at $V_\pi/2$, or quadrature, allows the device to operate in the most linear portion of the transfer function. Therefore, modulator bias can affect the linearity of the modulator response, which in turn affects the overall linearity of the link. Fiber nonlinearities are usually ignored, since, except for loss, they have no noticeable effect on the RF signal at the laser power levels common in RF links. Finally, the photodetector may insert random noise in the form of shot noise. In addition, as with all physical systems operating above absolute zero, thermal noise is also inserted into the output RF signal. Finally, the link components, especially the modulator, introduce higher-order harmonics into the signal. The largest of these harmonic distortions which falls in the bandwidth of the link is the third-order harmonic, typically specified as the third-order intercept point, or IP_3. Since IP_3 is a measure of the level of the original signal is to the third-order harmonic level, a higher number is better. As mentioned earlier, biasing the modulator at quadrature minimizes the nonlinearities of this device and minimizes the third-order harmonics it generates.

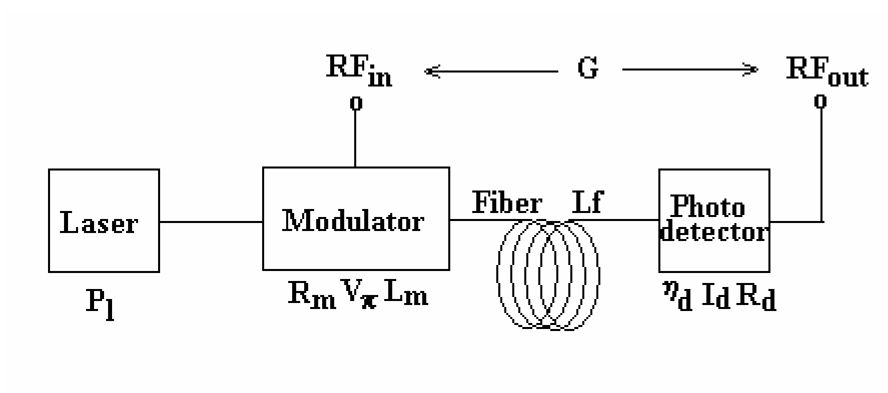

Figure 1: Externally Modulated RF Link

The first generation of the test-bed was meant to represent the state of the art in commercial components, with flexibility to extend the frequency range of the link into X band, or up to 10.5 GHz. Components were selected based on the assumption that the link would be used in the 1-11GHz range, although the bandwidth used at any one time would not be greater than 10-15%. Using this assumption, state of the art components were selected, and are listed in Appendix 1. A preamplifier at the input to the modulator was also added to the system to meet minimum gain requirements of the system

After component selection, the RF link's performance was calculated based on the procedure in [1], which is presented in the MathCAD calculations in Appendix 2. These calculations were based on a few assumptions. First, the modulator is assumed to be biased at quadrature. This is the most linear portion of the modulator's transfer function, and is the point at which IP_3 is the highest. Second, the fiber loss is assumed to be negligible. In the case of such a short distance, the fiber losses are indeed very small. Finally, the (RF) impedance of all components in the link are assumed to have a nominal impedance of 50 Ω. Although the matching circuits in the components are periodic in frequency, the impedance is close to 50 Ω. Comparisons of actual and calculated link performance will be explored in the testing results section of this document.

4.0 Link Construction

The first task in the construction phase of the link was to install the fiber optic cable assembly in the radar facility. The cable assembly consists of a 100 meter bundle of 24 individual single-mode fibers assembled into a bundle and housed in an environmentally sealed sheath. The cable assembly is rated for temperatures ranging from -40°C to +85°C. The fibers are standard single-mode 9 μm core, 125 μm cladding fibers, and the diameter of the entire cable is only 8.5 mm. Standard FC/PC connectors are installed at each end of the bundle to facilitate easy changes in the system, including removal of the transmitter and receiver boxes. Factory tests showed that each fiber had a maximum loss of not more than .3 dB, including the connectors.

The cable assembly installation began in room C-254 of building 106, the room that houses many of the electronics for the radar system, and which is closest to the radar tower on the east side of building 106. This allowed for easily feeding the cable through the cable run on the tower support structure and into the control room at the top of the tower with minimal effort. The cable assembly was then fed up into the radome, and enough cable was run into the area of the antenna array to ensure easy access to the antenna's RF outputs. Next, the cable was run in the opposite direction from the electronics room in a cable tray that runs over the vehicle bay in bldg 106, above IFTC's advanced computing architecture lab, then on to the radar surveillance area, terminating in room F-251.

Extreme care was taken not to kink the cable to less than 3" radius bends at any time during installation to avoid micro- and/or macro-bending losses. Where possible, permanent bends were restricted to not less than 6". Some other installation issues surfaced during the cable routing. The cable tray on the tower support structure was difficult to reach safely, and extreme caution had to be used during this phase. The SNDP and SNRT Safety Officers were present and mandated the use of a safety harness for all work on the support structure. Since the entire C-Band radar antenna platform rotates, care was taken to ensure that there was enough extra cable at the base of the platform to allow complete rotation of the platform without damage to the cable assembly. We mirrored the existing RF cables to ensure we met this requirement. Installation of the cable also required coordination with IFTC's Robert Brass to gain access to the cable tray above the IFTC Advanced Computing Architecture Lab. We also coordinated with James Van Damme of SNRT during the entire installation process to ensure access to rooms C-254 and F-251. It is desirable to have access to the secure surveillance facility added to your

RRS badge, since room F-251 is in this area. This allows unescorted access to the facility, and can be coordinated through the SNRT office.

After installation, we used an Optical Time-Domain Reflectometer (OTDR) to ensure that none of the fibers in the cable had been damaged during the installation. This device sends out a pulse of light along the fiber being tested and waits for a reflection to come back to the instrument, much like a SONAR system. Any break or lossy area will reflect some amount of light, and the timing and intensity of reflections will allow pinpointing of any problems with a fiber. To speed up testing, we used a patch cable to connect two fibers together at the far end of the cable assembly, enabling us to check two fibers during each test. One person was positioned at the test set, while another waited in the antenna radome to move the patch cord between pairs of fibers. Radio contact was maintained throughout this test to coordinate the testing and to prevent exposure to the laser pulses while swapping the patch cord. During the initial tests, an anomaly seemed to present itself. No matter what fiber was tested, there seemed to be a high loss in the fiber approximately 200 meters from the test set. All fibers seemed to have this problem, but then we reversed the direction of the light pulse, with the same effect. After speaking to Net Test, Inc., the current support company for this test equipment, we realized that this anomaly was a well-known problem with OTDRs, caused by the propagation of the laser light in the cladding of the fiber. This light gets reflected back and forth at discontinuities in the cladding until it finally comes back to the instrument and generates a “bump” on the trace display. This problem can be remedied by using a long (in excess of 1 km) patch fiber between the test set and the fiber under test, since the cladding is more lossy than the core of the fiber, and the light level in the cladding is reduced to a very low level after approximately 1 km. Although the “bump” is still visible at approximately 200 meters, it is reduced to an acceptable level, and accurate measurements can be made. After using this method, we found that none of the fibers had excessive losses, and all had the same losses as when tested by the manufacturer, Fiber Instrument Sales. A sample OTDR trace is shown in figure 2.

After installing the fiber cable assembly, the next step was to design and build the transmitter and receiver boxes, which are shown in Figures 3 and 4, respectively. Since the initial tests would be performed on just one channel, but we planned to later increase the number of channels to five, the power supplies we decided to use are robust enough to supply power to all components of a five-channel box. The same power supply, a triple output 150W supply, was used for both boxes. This allowed interchangeability and thus allowed a reduction in spare parts by 50%. The boxes were constructed of aluminum, with lids to protect users from shock hazards. Due to the modular nature of the boxes, the boxes were constructed larger than would otherwise be necessary, to allow for adequate room for changing components. Both boxes also contain the necessary RF and optical connectors for connection to the radar set and the fiber optic cable assembly. The datasheets for all commercial components in the link are included in Appendix 1.

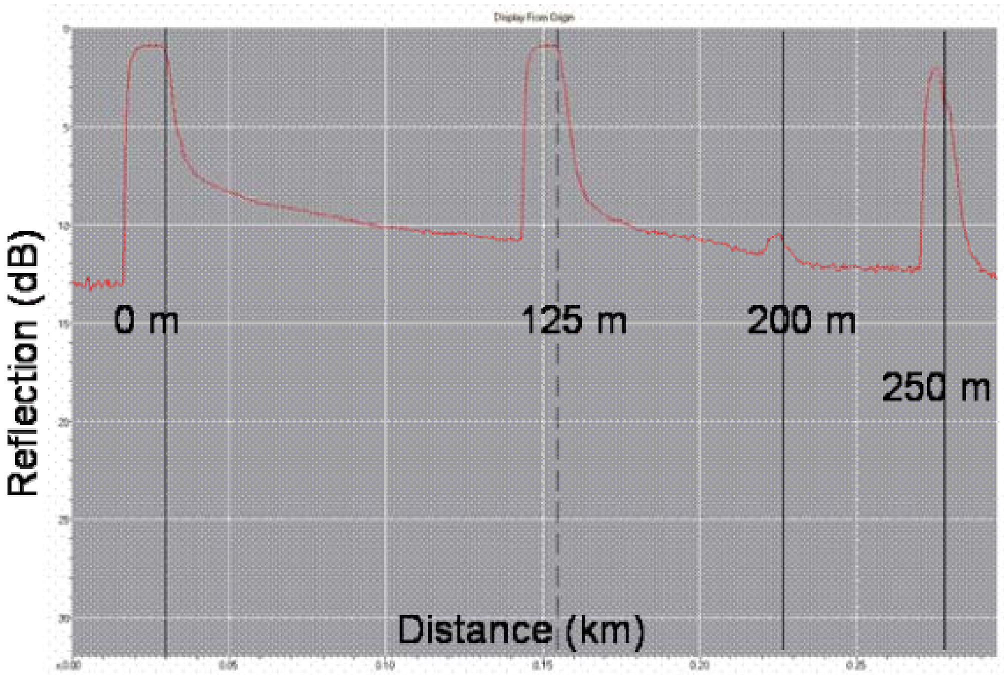

Figure 2: OTDR Trace Showing Anomaly

The transmitter box was built first. It houses a JDS Uniphase laser, which can supply a stable 1550 nm continuous output in excess of 40 mW, which is more than adequate for this task, given current limits on the maximum optical power on a commercially-available photo-detector, which is usually around 10 mW. The laser is regulated by two devices, both from ILX Lightwave: A laser driver, which regulates the DC power to the laser, and thereby its output optical power, and a temperature controller, which regulates the laser's temperature, protecting this heat-sensitive device from excess heat. The laser output is fed into a JDS Uniphase Lithium Niobate Mach-Zender Modulator, which impresses the input RF signal onto the laser light. The DC bias point of the modulator is currently controlled manually, which is adequate for this round of testing, but an automatic bias controller will need to be added later for long-term operation. The input RF signal is amplified before it is fed into the modulator by a MITEQ low-noise amplifier (LNA), which reduces the noise figure of the overall link to an acceptable level.

The receiver box houses the power supply and a single Discovery DSC-401ER photo-receiver. This receiver incorporates a photo-detector and amplifier in one package, and is capable driving a load directly. Initially, a low-noise amplifier was added to the output of the photo-receiver, but this was removed because it actually reduced the dynamic range of the link.

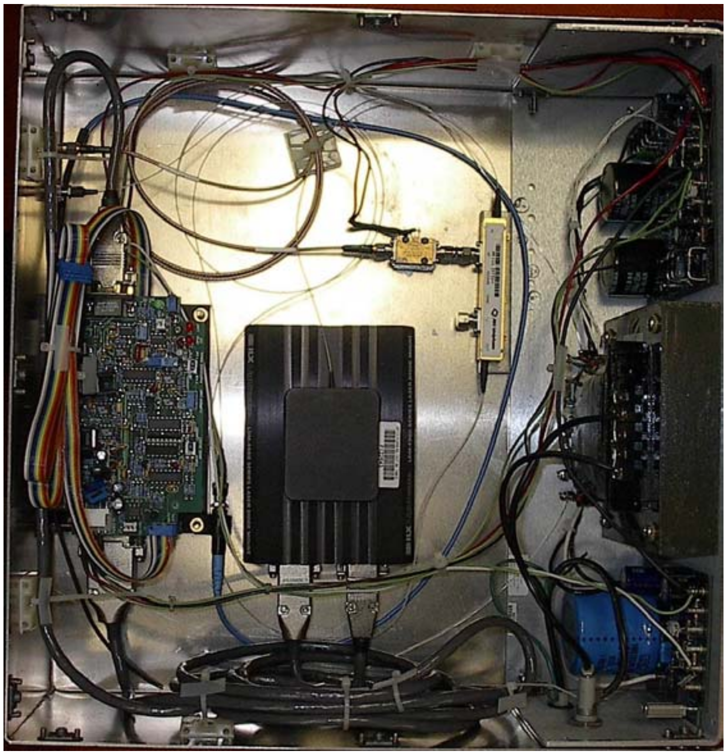

Figure 3: RF Link Transmitter

During construction of the boxes, very few problems were noted. The power supplies chosen performed well, and will easily be able to power a five-channel array of links. Since the laser bias and temperature controllers used are meant to be installed in a manufacturer's end product, it took some experimenting to set the controls for desired operation. The ILX Lightwave website [2] provided many application notes to help with this process, and should be referred when using these products. No other problems surfaced during the construction of the transmitter and receiver boxes.

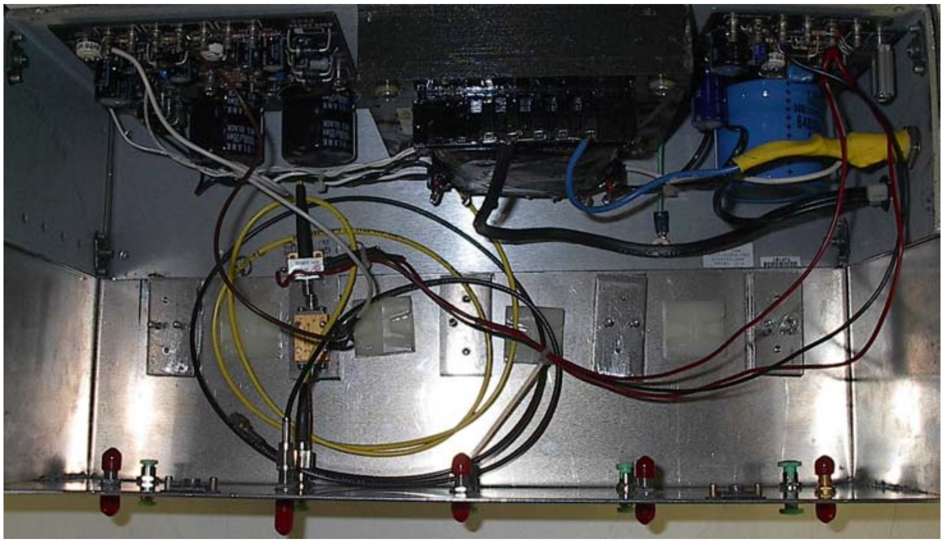

Figure 4: RF Link Receiver

Since the limiting factor in the transmitter for this system is the maximum allowable optical power at the photo-detector, the laser power was adjusted to 10 dBm at the input connector of the photo-detector. This was near the upper end of the linear range of the photo-detector, according to the manufacturer. After the losses associated with the photo-detector connector and losses at the interface between the photo-detector and it's input fiber, this should allow a margin of error to ensure that the photo-detector is not introducing excess nonlinearities into the link's overall performance.

5.0 Testing

After construction of both the transmitter and receiver was completed, the next step was to test the link as a whole. There are two ways to approach this testing: Treating the system as a group of components, testing each alone or in groups; or to treat the RF link as a black box, considering the link as one block, with specific performance characteristics that can be easily relayed to a user. Since the purpose of this program is to gain insight into how link different link components affect the overall radar system, the best approach in this case is to look at the RF link as a block, with input and output characteristics and its own transfer characteristics. That way, we can characterize the link in the same manner that any other radar component would be characterized. Even though photonic researchers can look at how the internal components affect the RF performance of the device, the radar designer who incorporates this link into their system only sees the RF performance specifications, which are the ones that matter to him/her.

To this end, there were several main specifications that were tested in this link. First, the amount of RF gain, or loss, of a block is a primary concern to radar engineers. Next, noise figure, or the amount of noise that a block adds to a system, is a major concern, especially in a radar system, where signal levels are usually very low. Finally, distortion of the signal is another fundamental characteristic of a block. The third-order intermodulation product, or IP_3, is the most commonly used specification for distortion for analog RF systems. When two signals, at frequencies f_1 and f_2, interact in a nonlinear device such as a diode, they produce several other tones at different frequencies. The most difficult intermodulation distortions to deal with are the ones at the frequencies $(2*f_1-f_2)$ and $(2*f_2-f_1)$ because these lie in the pass-band of the system's filters. Because these intermodulation products increase in magnitude three times faster than the fundamental output signals with increasing input power, the normal way to quantify these distortions is to extrapolate the point at which the input power level would cause the output fundamental and intermodulation products to be equal. This is the classic IP_3.

The spurious-free dynamic range (SFDR) of a system is the range of input power levels between which an input signal will be above the noise floor of the system (set by thermal noise and the noise figure of the system) and below the level where signal is so large that the system begins to become saturated (normally the 1 dB compression point). A good description of IP_3 and SFDR calculation can be found in [3]. Using the IP_3 and the noise figure (NF) of a system, the dynamic range can be calculated as $SFDR = 2/3 * (IP_3 – NF – \text{input noise floor})$.

Testing of the RF link consisted of looking at the RF gain (G), noise figure (NF) and IP_3 of the overall link, and then calculating the dynamic range of the link from those measurements. The results are given in Table 1. These results are somewhat different from the predictions in Appendix 2 for several reasons. First, the noise figure was higher than expected. This was probably due to differences between the noise figures and gain listed on the generic datasheets and the actual values of the individual components. Also, the RIN of the laser may have been higher than specified, causing more noise in the system. Finally, the power supply used may be contributing excess noise to the overall system. The overall IP_3, and accordingly, the SFDR are very sensitive to variations of individual components, and IP_3 can be difficult to predict. Overall, the predictions are close to the experimental data.

Freq (GHz)	NF (dB)	Gain (dB)	IP3 (dBm)	SFDR (dB/Hz^2/3)
1.00	5.98	20.71	-3.75	109.51
1.47	**6.51**	**19.15**	**-4.83**	**108.44**
1.95	6.98	18.44	-5.30	107.82
2.42	7.00	18.59	-2.80	109.47
2.89	7.51	19.24	-3.00	108.99
3.36	7.81	17.75	-6.45	106.49
3.84	8.08	17.39	-6.55	106.25
4.31	8.20	18.05	-6.05	106.50
4.78	8.41	17.53	-6.10	106.33
5.25	9.08	16.50	-7.10	105.21
5.73	9.43	16.10	-7.45	104.75
6.20	9.63	16.55	-7.90	104.31
6.67	9.60	17.12	-7.10	104.87
7.14	10.17	17.02	-8.05	103.85
7.62	10.85	16.38	-8.25	103.27
8.09	11.55	16.18	-8.00	102.97
8.56	12.23	15.89	-6.95	103.21
9.03	12.59	16.15	-7.55	102.57
9.51	13.01	16.01	-7.20	102.53
9.98	13.33	16.08	-9.00	101.11
10.45	13.88	15.64	-8.20	101.28

Table 1: RF Link Performance Results

Since SNRT's radar personnel would like to see acceptable performance at around 1.5 GHz, the IF frequency for the C-Band radar set, the following discussion will use the measured and calculated link performance at that frequency. As can be seen from Table 1 above, this RF link did not meet the performance goals set out in the beginning of this report, nor did it meet the calculated performance shown in Appendix 2. The noise figure of the link was 6.51 dB, 1.55 dB above the calculated value, but only .51 dB above the maximum requirements. The measured link RF gain was 19.15 dB, 3 dB above the calculated value. SNRT personnel did not state a specific gain requirement, except that they would like to see some positive gain. The actual IP_3

of the link was -4.83 dBm, 2.32 dBm worse than the theoretical value. Finally, the link's dynamic range was shown to be 108.44 dB/Hz$^{2/3}$, 9.18 dB lower than expected, and 15.23 dB below the requirement.

6.0 Summary and Conclusions

What does these test results mean? As we expected, the link does not meet the required performance goals set by the radar community, but it does provide a capability for the RF Links program, consisting of both in-house and contractual efforts, to measure progress toward those goals. Improvements can be made to reduce the noise figure and increase the overall dynamic range of the link, to the point that a similar link can become an integral part of a radar system, and some of these improvements, as highlighted by this effort, are listed below.

First, a more complete model must be developed, taking into account of such factors as interconnecting cables, which were largely ignored in the calculations in Appendix 2, must be taken into account. Although these cables are almost lossless, they do introduce some loss into the system, which reduces the overall gain and could add to the noise of the system. Also, modulator losses, both RF and optical, must be characterized and incorporated into the model. By accounting for these differences from the "ideal" case, we can more accurately predict the performance of the link. This may involve getting more data from the component manufacturers, or it may involve testing components for such performance specifications as noise figure and IP_3. In particular, establishing a capability to test the IP3 of photo detectors, such as with four-wave mixing, would be beneficial. Most component suppliers do not test detector IP_3.

Second, better bias control for the modulator must be incorporated into the system. During this experiment, a simple DC bias was used because the modulator is designed to be at quadrature, the optimal bias point for analog modulators, with no bias voltage applied. However, with laser light and/or a DC bias applied, all modulators tend to have some drift away from quadrature. Since this link was not used for long periods of time, it made sense not to incorporate an active bias controller into the system in the first generation, but later links will most likely become an integral part of the radar system, and must therefore have an active bias control system, such as those available from Photonics Systems (Models PSI 02XX or PSI03XX) or Opnext (Micro-MBC and Mini-MBC).

Finally, the entire RF link, including the electro-optic modulator, must be made more linear. As can be seen from the calculations in Appendix 2, the overall dynamic range is affected by noise figure and the third-order intermodulation product. Since the calculated noise figure is less than 2 dB above Cox's noise figure minimum limit for an RF link [4], the remaining factor that can increase dynamic range is the overall IP_3. The single biggest contributor to the sub-optimal IP_3 of the photonic section of the link is the modulator. If the modulator can be made more linear, which means reduced intermodulation products, and thus a better IP_3, then the overall link dynamic range will improve. Work is currently ongoing in SNDP to solve this part of the problem.

After the problems above are solved, or at least mitigated, the next logical step in this project will be to modify the existing link with the improvements mentioned above. After testing confirms that the next generation of RF link meets the requirements mentioned above for insertion into the radar set, it should be inserted into the that system. The feedback from SNRT's radar experts will then be used as input for the construction of a five-channel test-bed. This test bed will increase the Photonics Center's ability to evaluate current and future components, both commercial and developmental, and how they will affect an RF photonic link's performance, as well as the effect these components will have on the operational radar sets they will become a part of. This is a key step in incorporating photonics into radar and other RF systems to make smaller, lighter and more agile systems for use by our warfighters.

Appendix 1: List of Attached Component Datasheets

1. 150W Power Supply, Power-One, Inc., Model No. HDCC-150W-A
2. Low Noise Amplifier, MITEQ, Inc., Model No. AMF-4D-001120-24-10P
3. 1550 nm CW DFB Laser Diode, JDS Uniphase, Model No. CQF935-708
4. Laser Diode (LD) Mount, ILX Lightwave, Model No. 4984
5. LD Current Source, ILX Lightwave, Model No. LDX-3100
   LD Temperature Controller, ILX Lightwave, Model No. LDT-5100
6. Mach-Zender Electro-Optic Modulator, JDS Uniphase, Model No. APE Microwave
7. Low-Noise Optical Receiver, Discovery Semiconductors, Inc., Model No. DSC-401ER
8. MITEQ Self-Contained Photonic Link

Note: Appendix page numbers follow the general pattern: A.AppendixNumber.ItemNumber.ItemPage, i.e. for the first page of the Power-One power supply, the page number is A.1.1.1

Note: All boxes and spare components for this project are stored in Building 104, Lab 41 at the Rome Research Site as of 23 July, 2004

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Single Output Models

VOLTAGE	MODEL	VOLTAGE/ CURRENT	CASE SIZE
	HA5-1.5/OVP-A	5V @ 1.5A (Note 1)	B
	HB5-3/OVP-A	5V @ 3A (Note 1,5)	B
	HC5-6/OVP-A	5V @ 6A (Note 1,5)	C
	HN5-9/OVP-A	5V @ 9A (Note 1,5)	N
5V	**HD5-12/OVP-A**	5V @ 12A (Note 1,5)	D
	HE5-18/OVP-A	5V @ 18A (Note 1,5)	E
	F5-25/OVP-A	5V @ 25A (Note 1,5,6,10)	F
	G5-35/OVP-A	5V @ 35A (Note 1,5,6,10)	F
	CP197-A	5V @ 50A (Note 1,5,6,10)	F
	HA15-0.9-A	12V @ 0.9A (Note 2)	B
	HB12-1.7-A	12V @ 1.7A (Note 5)	B
	HC12-3.4-A	12V @ 3.4A (Note 5)	C
12V	**HN12-5.1-A**	12V @ 5.1A (Note 5)	N
	HD12-6.8-A	12V @ 6.8A (Note 5)	D
	HE12-10.2-A	12V @ 10.2A (Note 5)	E
	F15-15-A	12V @ 16A (Note 2,5,6,10)	F
	HA15-0.9-A	15V @ 0.9A (Note 2)	B
	HB15-1.5-A	15V @ 1.5A (Note 5)	B
	HC15-3-A	15V @ 3A (Note 5)	C
15V	**HN15-4.5-A**	15V @ 4.5A (Note 5)	N
	HD15-6-A	15V @ 6A (Note 5)	D
	HE15-9-A	15V @ 9A (Note 5)	E
	F15-15-A	15V @ 15A (Note 2,5,6,10)	F

VOLTAGE	MODEL	VOLTAGE/ CURRENT	CASE SIZE
	HA24-0.5-A	24V @ 0.5A (Note 2)	B
	HB24-1.2-A	24V @ 1.2A (Note 5)	B
	HC24-2.4-A	24V @ 2.4A (Note 5)	C
24V	**HN24-3.6-A**	24V @ 3.6A (Note 5)	N
	HD24-4.8-A	24V @ 4.8A (Note 5)	D
	HE24-7.2-A	24V @ 7.2A (Note 5)	E
	F24-12-A	24V @ 12A (Note 2,5,6,10)	F
	HA24-0.5-A	28V @ 0.5A (Note 2)	B
	HB28-1-A	28V @ 1A (Note 5)	B
	HC28-2-A	28V @ 2A (Note 5)	C
28V	**HN28-3-A**	28V @ 3A (Note 5)	N
	HD28-4-A	28V @ 4A (Note 5)	D
	HE28-6-A	28V @ 6A (Note 5)	E
	F24-12-A	28V @ 10A (Note 2,5,6,10)	F
	HB48-0.5-A	48V @ 0.5A	B
48V	**HC48-1-A**	48V @ 1A	C
	HD48-3-A	48V @ 3A (Note 5)	D
	HE48-4-A	48V @ 4A (Note 5)	E

NOTES:
1) Overvoltage protection provided. Set at 6.2V ±0.4V.
2) Adjustable outputs: F15-15-A: 12-15V, F24-12-A: 24-28V, HA15-0.9-A: 12-15V, HA24-0.5-A: 24-28V.
3) Nonadjustable 3 terminal regulator.
4) Isolated outputs, can be referenced as positive (+) or negative (-).
5) Remote sense provided.
6) With output inhibit and parallel operation master/slave capability.
7) With output inhibit.
8) Adjustable 3 terminal regulator.
9) Can be made into an isolated output by removing jumper W1.
10) Model requires forced-air cooling above 75% of rated output power at 50°C as follows: F5-25/OVP-A (200 LFM), G5-35/OVP-A (100 LFM), CP197-A (300 LFM), F15-15-A (250 LFM), and F24-12-A (100 LFM).

Dual Output Models

VOLTAGE	MODEL	OUTPUT # 1	OUTPUT # 2	CASE SIZE
±5V	**HAA5-1.5/OVP-A** **HBB5-3/OVP-A** **HCC5-6/OVP-A**	+5V @ 1.5A (Note 1) +5V @ 3A (Note 1) 5V @ 6A (Note 1,4,5)	-5V @ 1.5A (Note 1) -5V @ 3A (Note 1) 5V @ 6A (Note 1,4,5)	AA BB CC
± 12V	**HAD12-0.4-A**	+12V @ 0.4A (Note 3)	-12V @ 0.4A (Note 3)	B
± 15V	**HAD15-0.4-A**	+15V @ 0.4A (Note 3)	-15V @ 0.4A (Note 3)	B
±12V to ±15V	**HAA15-0.8-A**	+12V @ 1A or +15V @ 0.8A (Note 5)	-12V @ 1A or -15V @ 0.8 or -5V @ 0.4A (Note 5)	AA
	HBB15-1.5-A	+12V @ 1.7A or +15V @ 1.5A (Note 5)	-12V @ 1.7A or -15V @ 1.5A or -5V @ 0.7A (Note 5)	BB
	HCC15-3-A	+12V @ 3.4A or +15V @ 3A (Note 5)	-12V @ 3.4A or -15V @ 3A (Note 5)	CC
	HDD15-5-A	+12V or 15V @ 5A (Note 5)	(-)12V or 15V @ 5A	E
±18V ±24V	**HAA24-0.6-A**	+18-20V @ 0.4A or +24V @ 0.6A	(-)18-20V @ 0.4A or -24V @ 0.6A	AA
	HBB24-1.2-A	+18-20V @ 0.9A or +24V @ 1.2A	(-)18-20V @ 0.9A or -24V @ 1.2A	BB
	HCC24-2.4-A	+18-20V @ 1.8A +24V @ 2.4A (Note 5)	(-)18-20V @ 1.8A -24V @ 2.4A (Note 5)	CC
5V and 12V-15V	**HAA512-A** **HBB512-A** **HCC512-A**	5V @ 2A (Note 1,4,5) 5V @ 3A (Note 1,4,5) 5V @ 6A (Note 1,4,5)	12-15V @ 0.5A (Note 4) 12-15V @ 1.25A (Note 4,5) 12-15V @ 2.5A (Note 4,5)	AA BB CC

Triple Output Models

MODEL	OUTPUT # 1	OUTPUT # 2	OUTPUT # 3	CASE SIZE
HTAA-16W-A	5V @ 2A (Note 1,4)	+12 to 15V @ 0.4A	(-)12 to 15V @ 0.4A or -5V @ 0.4A	AA
HBAA-40W-A	5V @ 3A (Note 1,4,5)	+12V @ 1A or +15V @ 0.8A (Note 5)	-12V @ 1A or -15V @ 0.8A or -5V @ 0.4A (Note 5)	BAA
HCAA-60W-A	+5V @ 6A (Note 1,5)	+12 to 15V @ 1A	(-)12 to 15V @ 1A or -5V @ 0.4A	D
HCBB-75W-A	5V @ 6A (Note 1,4,5)	+12V @ 1.7A or +15V @ 1.5A (Note 5)	-12V @ 1.7A or -15V @ 1.5A or -5V @ 0.7A (Note 5)	CBB
CP131-A	5V @ 8A (Note 1,4,5)	+12V @ 1.7A or +15V @ 1.5A (Note 5)	-12V @ 1.7A or -15V @ 1.5A or -5V @ 0.7A (Note 5)	CP131
HDBB-105W-A	5V @ 12A (Note 1,4,5)	+12V @ 1.5A or +15V @ 1.5A (Note 5)	-12V @ 1.7A or -15V @ 1.5A or -5V 0.7A (Note 5)	DBB
HDCC-150W-A	5V @ 12A (Note 1,4,5)	+12V @ 3.4A or +15V @ 3A (Note 5)	-12V @ 3.4A or -15V @ 3A	DCC

NOTES:
1) Overvoltage protection provided. Set at 6.2V ±0.4V.
2) Adjustable outputs: F15-15-A: 12-15V, F24-12-A: 24-28V, HA15-0.9-A: 12-15V, HA24-0.5-A: 24-28V.
3) Nonadjustable 3 terminal regulator.
4) Isolated outputs, can be referenced as positive (+) or negative (-).
5) Remote sense provided.
6) With output inhibit and parallel operation master/slave capability.
7) With output inhibit.
8) Adjustable 3 terminal regulator.
9) Can be made into an isolated output by removing jumper W1.
10) Model requires 100 LFM forced air cooling above 75% of rated output power at 50°C.

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High Peak Models

MODEL	OUTPUT # 1	OUTPUT # 2	OUTPUT # 3	OUTPUT #4	CASE SIZE
CP323-A*	+5V @ 2A (Note 1)	+12 @ 4A (Note 7)			N
CP162-A*	+5V @ 3A (Note 1,5)	-5V @ 0.6A (Note 1)	24V @ 5A/ or 6APK (Note 4,5)		CP131
CP510-A*	+5V @ 6A (Note 1)	+12V @ 2.5A/ 7.5APK			CP510-A
CP379-A*	+5V @ 6A (Note 1,5,9)	-5V @ 1.2A or -12V @ 1.2A (Note 8)	24V @ 3.5A/ 8APK (Note 4,5)		CP131
CP498-A*	+5V @ 6A (Note 1,5)	+12V @ 5A/10APK (Note 5)	12V @ 0.5A or 5V @ 0.25A (Note 4,8)		CP131
CP503-A*	+5V @ 6A (Note 1)	+12V @ 1A	-12V @ 1A or -5V @ 0.5A	+24V @ 2.4A/ 4APK (Note 9)	CP131

NOTES:
1) Overvoltage protection provided. Set at 6.2V ±0.4V.
2) Adjustable outputs: F15-15-A: 12-15V, F24-12-A: 24-28V, HA15-0.9-A: 12-15V, HA24-0.5-A: 24-28V.
3) Nonadjustable 3 terminal regulator.
4) Isolated outputs, can be referenced as positive (+) or negative (-).
5) Remote sense provided.
6) With output inhibit and parallel operation master/slave capability.
7) With output inhibit.
8) Adjustable 3 terminal regulator.
9) Can be made into an isolated output by removing jumper W1.
10) Model requires 100 LFM forced air cooling above 75% of rated output power at 50°C.

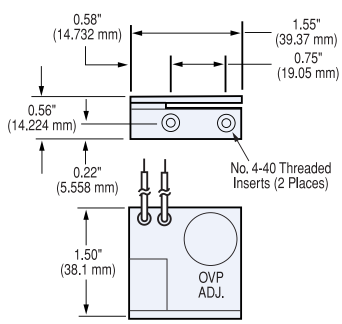
* Non-stocked standards

Overvoltage Protection Options

OVERVOLTAGE PROTECTION OPTIONS

These optional overvoltage protection modules are offered for use with Power-One's International Series Linear power supplies. Each is user adjustable from 6.4V to 34V.

OVP-12

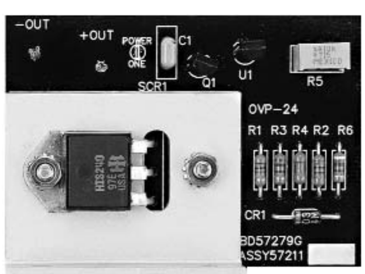


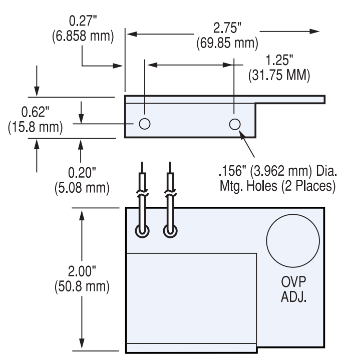
OVP SELECTION GUIDE

MODEL	CASE SIZE	OVP MODULES REQUIRED
SINGLE OUTPUT	B,C,N,D	(1) OVP-12
	E,F	(1) OVP-24
DUAL OUTPUT	AA,B,BB,CC	(1) OVP-12 protects both outputs
	E	(1) OVP-24 protects both outputs
TRIPLE OUTPUT	AA,BAA,D CBB, 131 DBB,DCC	(1) OVP-12 protects both 12V through 15V outputs
PEAK CURRENT MODELS	N,BAA,CBB 131, CP340-A CP510-A	(1) OVP-12 protects any output not provided with built-in OVP

NOTE: Outputs with factory built-in OVP are indicated in the Voltage/Current Rating Chart for each model. OVP is not available for 48V through 250V models.

OVP-24





Input Specifications

PARAMETER	CONDITIONS/DESCRIPTION		MIN	NOM	MAX	UNITS
Input Voltage - AC (Note 1, 2)	Jumper selectable, shipped factory configured for 120VAC operation. All models must be externally fused for proper operation. Fuse ratings are marked on each unit. Consult factory for each unit's fuse requirements.	100 VAC Tap 120 VAC Tap 220 VAC Tap 240 VAC Tap	87 104 191 209	100 120 220 240	110 132 242 264	VAC
Input Frequency	AC input.		47		63	Hz
Line Regulation	Output voltage charge for a 10% line change: F case models. HAD12, HAD15. Outputs with adjustable three terminal regulators. All other models.		-0.01 -1.0 -0.5 -0.05		+0.01 +1.0 +0.5 +0.05	%

NOTES: 1) Derate output current 10% for 50Hz operation.
2) Input voltage tolerance for 230VAC operation is +15%, -10%.

Output Specifications

PARAMETER	CONDITIONS/DESCRIPTION	MIN	NOM	MAX	UNITS
Output Adjustment	Minimum output adjustment range (Note 1).	-5		+5	%
Efficiency	5 volt outputs. 12 volt and 15 volt outputs. 24 volt and higher outputs.		45 55 60		%
Ripple and Noise (Note 2)	F case models. 5 volt, 12 volt, and 15 volt models. All three terminal regulator outputs.			3.0 5.0 0.2	mVPK-PK mVPK-PK %PK-PK
	24 volt through 250 volt models.	3.0mVPK-PK plus 0.02% of output voltage, max			
Load Regulation	Output change for a 50% load change: F case models. HAD12, HAD15. Outputs with adjustable three terminal regulators. All other models.	-0.02 -1 -0.5 -0.05		+0.02 +1 +0.5 +0.05	%
Transient Response	Recovery time, to within 1% of initial set point due to a 50% load change.			50	μs

NOTES: 1) **OUTPUT VOLTAGE ADJUSTMENTS:** Output voltage adjustments can be made to within ±5% of nominal voltage. Locate the "Vadj" potentiometer on the power supply PCB and use a screwdriver to adjust the output pot. The HAD12 and HAD15 3-terminal regulator outputs are not adjustable.
2) Full load, 20MHz bandwidth.

Safety, Regulatory, and EMI Specifications

PARAMETER	CONDITIONS/DESCRIPTION	MIN	NOM	MAX	UNITS
Agency Approvals	UL1950. CSA 1402 or CSA 22.2 No. 234/950. EN60950 (TÜV).		Approved		
Dielectric Withstand Voltage	Input to output. Input to ground.	3750 3750			VRMS
Electromagnetic Interference	FCC CFR title 47 Part 15 Sub-Part B - conducted. EN55022 / CISPR 22 conducted. EN55022 / CISPR 22 radiated.	Compatible with system compliance to Level B.			
Leakage Current	Per EN60950 (264VAC)		23	50	mA

Interface Signals and Internal Protection

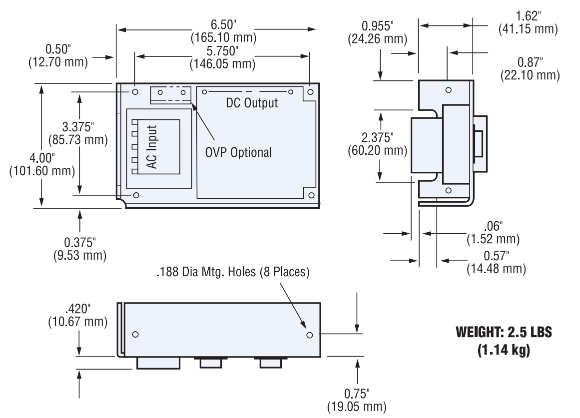
PARAMETER	CONDITIONS/DESCRIPTION	MIN	NOM	MAX	UNITS
Overvoltage Protection	Provided on 5 volt output units where indicated. Other outputs may use optional overvoltage protectors OVP-12 and OVP-24.	5.8		6.6	V
Remote Sense	Total voltage compensation for cable losses with respect to the main output. Provided on models where indicated.			250	mV
Overcurrent/Short Circuit Protection	Automatic current limit/foldback. Rated as a percentage of output power.	115	120	140	%
Master/Slave Operation	For parallel operation of up to 6 units. Master/slave pin provided on F case models only. Contact factory for application notes.				

Environmental Specifications

PARAMETER	CONDITIONS/DESCRIPTION		MIN	NOM	MAX	UNITS
Operating Temperature	Derate output power linearly above 50°C by 3% per °C.	At 100% load	0		50	°C
		At 40% load			70	°C
Storage Temperature			-40		85	°C
Temperature Coefficient	0°C to 50°C (after 15 minute warm-up).			0.1	0.3	%/°C
	24 hours after warm-up.		-0.3		+0.3	%
Shock	Operating.				20	GPK
Vibration	Random vibration from 10 Hz to 2 kHz, 3 axis.				6.15	GRMS

AA CASE

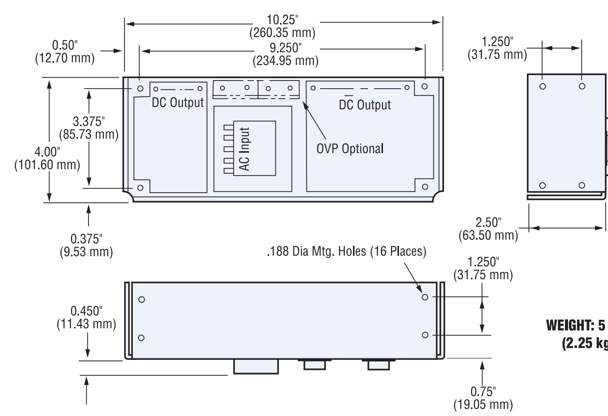
OVERALL SIZE
6.50" x 4.00" x 2.10"
(165.10 mm) x (101.60 mm) x (53.34 mm)



WEIGHT: 2.5 LBS
(1.14 kg)

BAA CASE

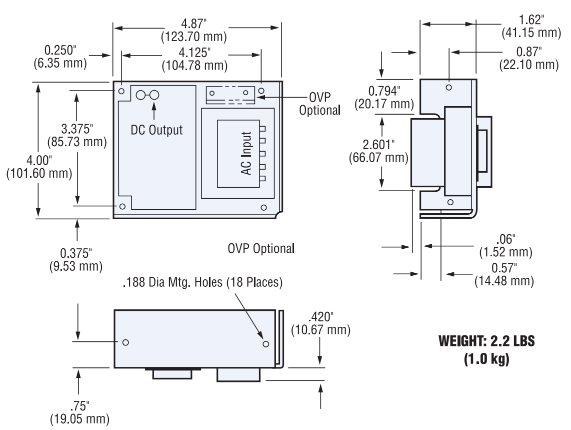
OVERALL SIZE
10.25" x 4.00" x 2.95"
(260.35 mm) x (101.60 mm) x (74.93 mm)



WEIGHT: 5 LBS
(2.25 kg)

B CASE

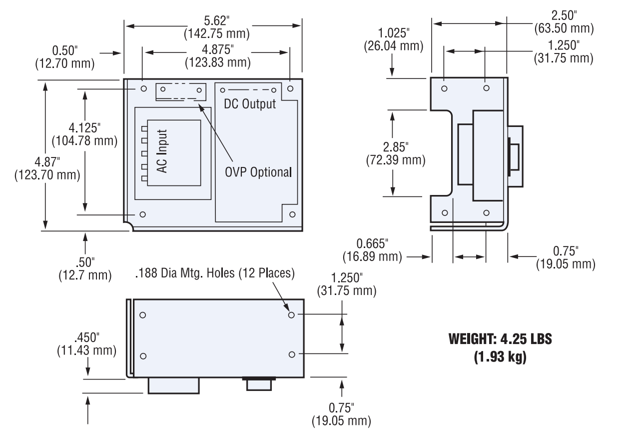
OVERALL SIZE
4.87" x 4.00" x 2.10"
(123.70 mm) x (101.60 mm) x (53.34 mm)



WEIGHT: 2.2 LBS
(1.0 kg)

C CASE

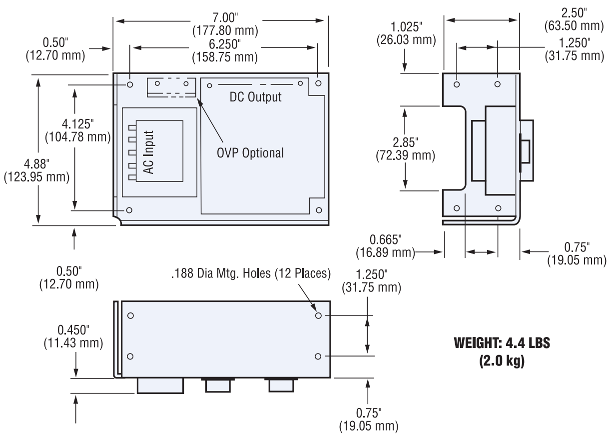
OVERALL SIZE
5.62" x 4.87" x 2.95"
(142.75 mm) x (123.70 mm) x (74.93 mm)



WEIGHT: 4.25 LBS
(1.93 kg)

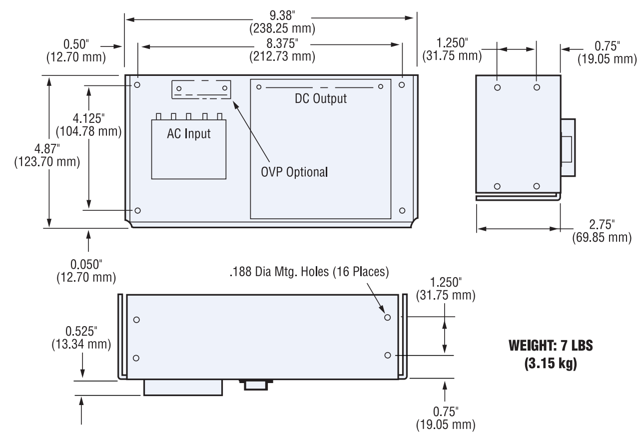
BB CASE

OVERALL SIZE
7.00" x 4.87" x 2.95"
(177.80 mm) x (123.70 mm) x (74.93 mm)



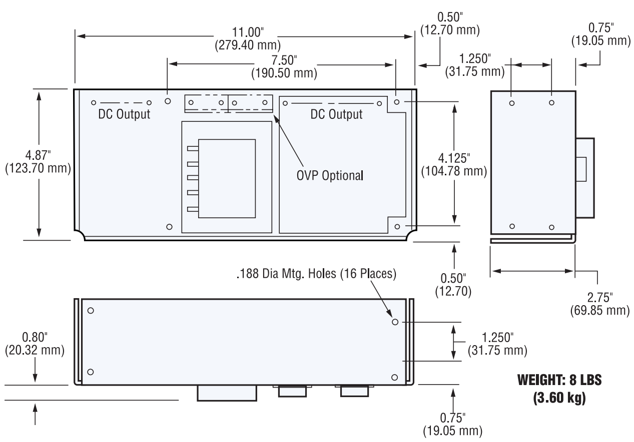
CC CASE

OVERALL SIZE
9.38" x 4.87" x 3.28"
(238.25 mm) x (123.70 mm) x (83.31 mm)



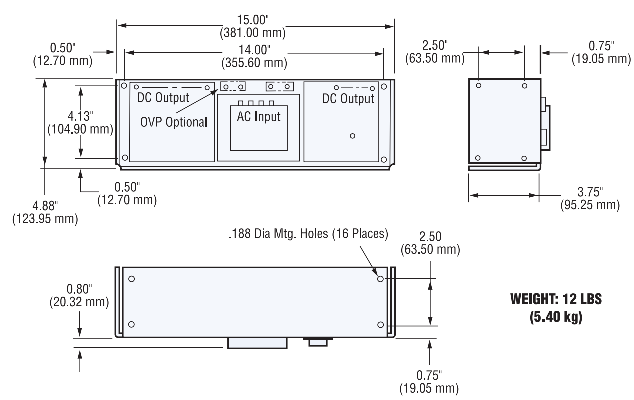
CBB CASE

OVERALL SIZE
11.00" x 4.87" x 3.28"
(279.40 mm) x (123.70 mm) x (83.31 mm)



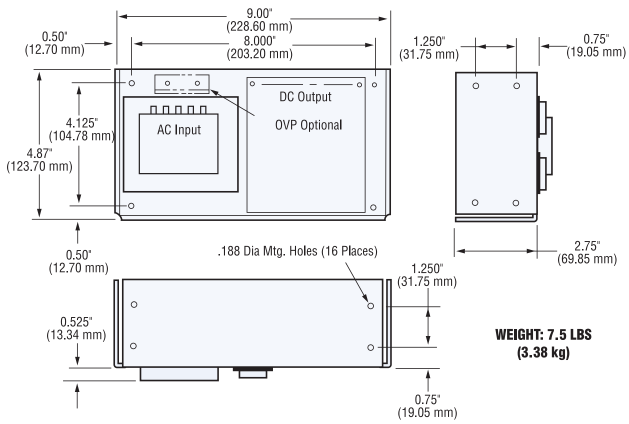
DCC CASE

OVERALL SIZE
15.00" x 4.88" x 4.55"
(381.00 mm) x (123.95 mm) x (115.57 mm)



D CASE

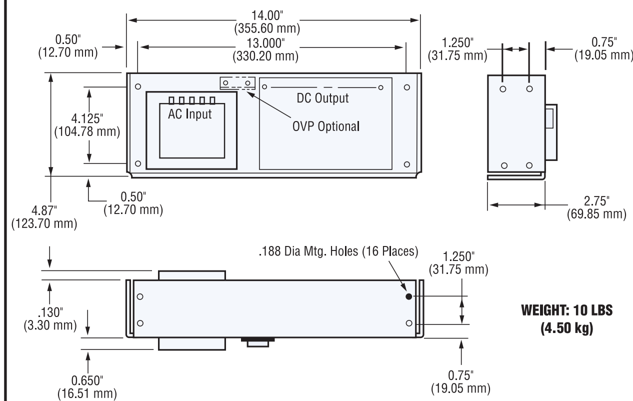
OVERALL SIZE
9.00" x 4.87" x 3.28"
(228.60 mm) x (123.70 mm) x (83.31 mm)



WEIGHT: 7.5 LBS (3.38 kg)

E CASE

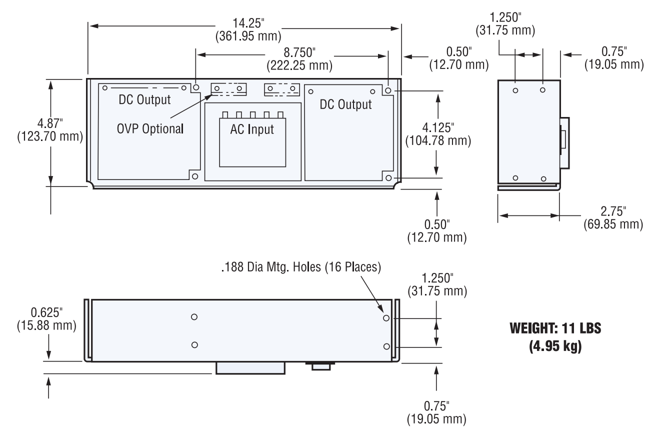
OVERALL SIZE
14.00" x 4.87" x 3.53"
(355.60 mm) x (123.70 mm) x (89.66 mm)



WEIGHT: 10 LBS (4.50 kg)

DBB CASE

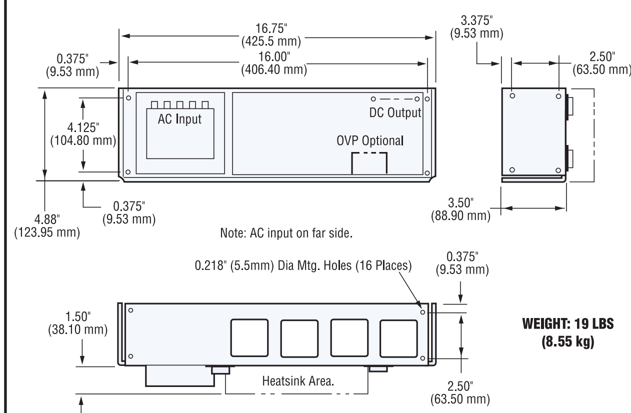
OVERALL SIZE
14.25" x 4.87" x 3.38"
(361.95 mm) x (123.70 mm) x (85.85 mm)



WEIGHT: 11 LBS (4.95 kg)

F CASE

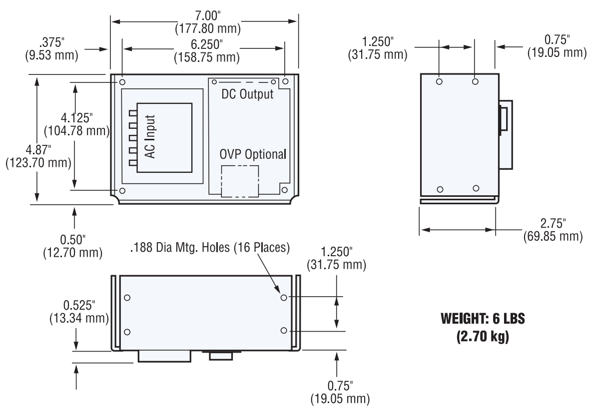
OVERALL SIZE
16.75" x 4.88" x 5.00"
(425.5 mm) x (123.95 mm) x (127.00 mm)



WEIGHT: 19 LBS (8.55 kg)

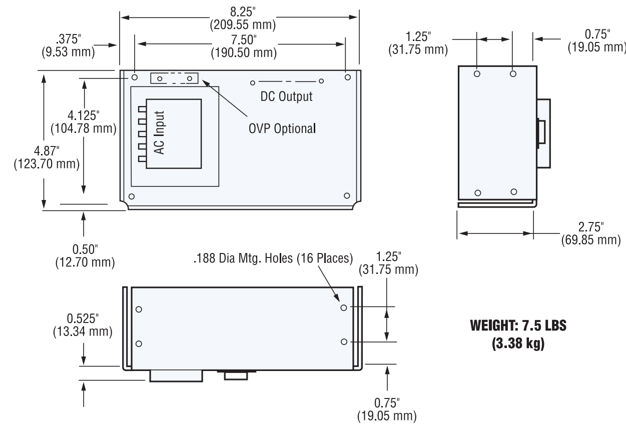
N CASE

OVERALL SIZE
7.00" x 4.87" x 3.28"
(177.80 mm) x (123.70 mm) x (83.31 mm)



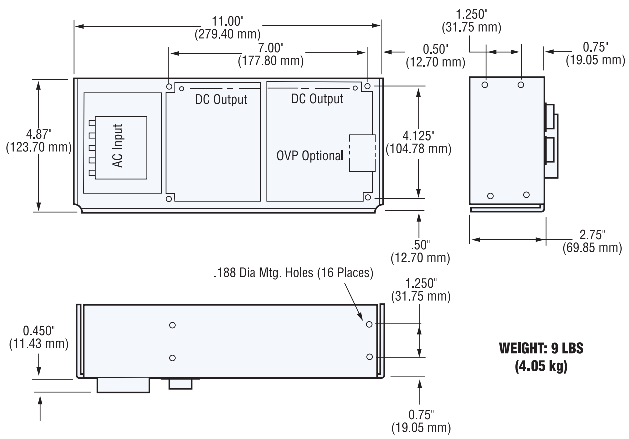
CP510-A CASE

OVERALL SIZE
8.25" x 4.87" x 3.28"
(209.55 mm) x (123.70 mm) x (83.31 mm)



CP131 CASE

OVERALL SIZE
11.00" x 4.87" x 3.28"
(279.40 mm) x (123.70 mm) x (83.31 mm)



NUCLEAR AND MEDICAL APPLICATIONS - Power-One products are not authorized for use as critical components in life support systems, equipment used in hazardous environments, or nuclear control systems without the express written consent of the respective divisional president of Power-One, Inc.

TECHNICAL REVISIONS - The appearance of products, including safety agency certifications pictured on labels, may change depending on the date manufactured. Specifications are subject to change without notice.

MITEQ

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Hauppauge, New York 11788-2086
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FAX : (631) 436-7430

Project :	P118862
Internal Transfer :	N / A
Customer P / N :	N / A
Customer P. O. :	939
Model Number :	AMF-4D-001120-24-10P
Serial Number :	899683

SPECIFICATIONS at +25°C :

Frequency (GHz)	0.1 to 12.0 GHz	P_{out} @ 1 dB Comp (dBm)	+ 10.0 dBm, minimum
Gain (dB)	36.0 dB, minimum	Output IP3 (dBm)	N / A
Gain Flatness (dB)	± 1.50 dB, maximum	Reverse Isolation (dB)	N / A
Δ Gain vs. Temp (dB)	N / A	Voltage (VDC)	+ 15.0 VDC
VSWR : Input / Output	2.00 : 1, max / 2.00 : 1, max	Current (mA)	160 mA, nominal
Noise Figure (dB)	2.40 dB, max *(0.2 - 12.0 GHz)*	Operating Temp (°C)	+ 25°C
	2.90 dB, max *(below 0.2 GHz)*	Outline Drawing	121623-4

NOTE 1 - This unit can safely handle a maximum input power of + 10.0 dBm, CW.
NOTE 2 - Adequate heat sinking is required to guarantee proper amplifier operation.

Measured Current
160.0 mA

TEST DATA at +25°C :

Frequency (GHz)	Noise Figure (dB)	P_{out} @ 1 dB Comp (dBm)	Output IP3 (dBm)	Frequency (GHz)	Noise Figure (dB)	P_{out} @ 1 dB Comp (dBm)	Output IP3 (dBm)
0.1	2.82	+ 12.0	N / A	4.0	2.02	+ 12.2	N / A
0.2	2.12	+ 12.0	N / A	6.0	2.17	+ 12.0	N / A
0.5	1.87	+ 11.8	N / A	8.0	2.05	+ 12.8	N / A
1.0	1.82	+ 11.6	N / A	10.0	2.16	+ 12.6	N / A
2.0	2.02	+ 11.4	N / A	12.0	2.30	+ 12.2	N / A

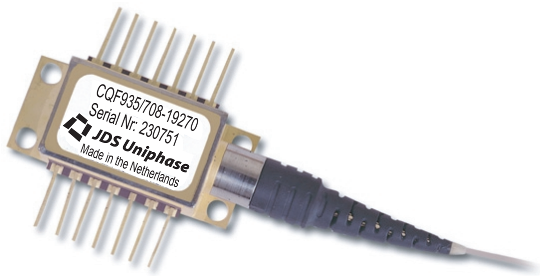
Max VSWR Input	Max VSWR Output
1.83 : 1	1.69 : 1

With 2 Output Signals Each At N / A dBm.
The 3rd Order IM Rejection is = N / A dB.

Tested By : DONAL C. M

Date : 9/24/02

Product Bulletin



40 mW 1550 nm CW DFB Laser with PM Fiber for WDM Applications

CQF935/708 Series

The CQF935/708 has been especially developed for use in WDM systems where it is used as a wavelength selected source in combination with an external modulator (such as a $LiNbO_3$-based Mach-Zehnder modulator).

The wavelengths that can be selected comply with the ITU recommendation both in range (channels ranging from 1527.61 to 1610.06 nm) and in channel definition, adhering to the 100 GHz grid (0.8 nm) relative to a frequency of 193.1 THz (i.e., a wavelength of 1552.52 nm). Customization of the wavelength spacing to a 50 GHz grid (0.4 nm) is possible. The wavelength of each laser is accurately measured and each laser is accompanied by a datasheet with the laser performance at the temperature T_λ where the required wavelength channel is reached.

The laser shows excellent side-mode suppression ratios (typically 45 dB), relative intensity noise (-160 dB/Hz maximum), and small linewidths (typically <1 MHz). The butterfly packaged laser is provided with a polarization maintaining fiber to facilitate coupling to the modulator and shows excellent thermal stability (e.g., wavelength drift with case temperature is better than 0.001 nm/°C).

Key Features

- 1550 nm (WDM) DFB laser diode
- High power (> 40 mW)
- Polarization maintaining fiber
- Built-in thermo-electric cooler
- Cooled built-in optical isolator
- 1527 - 1610 nm wavelength range
- 0.8 nm (100 GHz) spacing
- 0.4 nm (50 GHz) spacing optional

Applications

- In hybrid fiber-coax (HFC) networks, in cable-television (CATV) networks and in metro architectures where high power, low RIN, and narrow linewidths are required

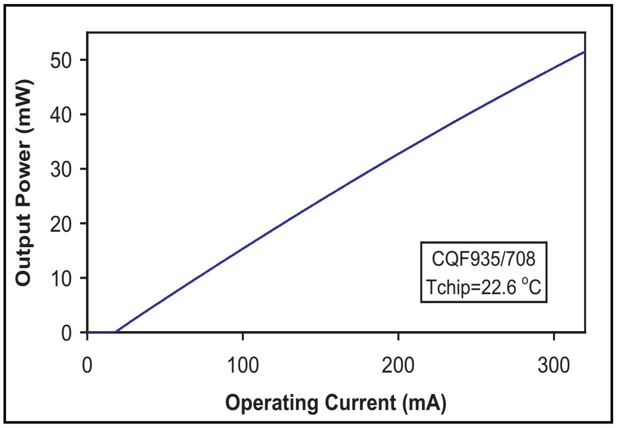
Specifications

Limiting Values						
Parameter	**Symbol**	**Conditions**	**Min**		**Max**	**Unit**
Laser Diode						
Radiant output power from pigtail	P_{peak}	-	-		100	mW
Reverse voltage	V_R	-	-		2.0	V
Forward current	I_F	-	-		600	mA
Monitor Diode						
Reverse voltage	V_R	-	-		20	V
Forward current	I_F	-	-		10	mA
Module						
Storage temperature range	T_{stg}	see note 1	-40		85	°C
Case operating temperature range	T_{op}	cooler active	0		65	°C
Fiber Pigtail						
Bending radius	R	-	35		-	mm
Tensile strength fiber to case	F	see note 1	-		5	N

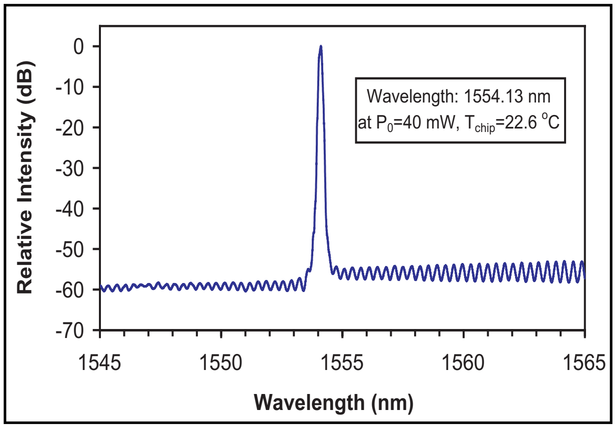
Characteristics ($T_{chip} = T_\lambda$, T_{amb} at 25 °C, P_O = 40 mW unless otherwise specified)						
Parameter	**Symbol**	**Conditions**	**Min**	**Typ**	**Max**	**Unit**
Radiant output power from pigtail	P_O	20 °C < T_λ < 35 °C	40		-	mW
Operating current	I_{op}	-	-	250	400	mA
Laser Diode						
Threshold current	I_{th}	-	-	25	40	mA
Xentral wavelength (ITU grid)	λ_c	-	1527	-	1610	nm
Laser set temperature for λ_c	T_λ	-	20	-	35	°C
Forward voltage	V_F	-	-	-	2.5	V
Side mode suppression ratio	SMSR	-	30	45	-	dB
Optical isolation	ISO	-	30	35	-	dB
Relative intensity noise	RIN	20 - 1000 MHz	-	-	-160	dB/Hz
Spectral linewidth	$\Delta\lambda$	FWHM	-	-	1	MHz
Wavelength drift with case temp.		0 °C < T_{case} < 65 °C	-	-	0.001	nm/°C
Wavelength temperature tunability		20 °C < T_λ < 35 °C	0.07	-	0.12	nm/°C
Monitor Diode (V_R = 10 V)						
Monitor diode responsivity	R	-	5	-	150	µA/mW
Dark current	I_{md}	-	-	-	0.1	µA
Temperature tracking error	TE	0 °C < T_{case} < 65 °C	-	-	10	%
Thermistor						
Resistance	R_{th}	T_{th} = 25 °C	9.5	10	10.5	kΩ
Thermistor constant	B	-	3800	-	4100	K
Thermo-Electric Cooler (ΔT = 45 °C)						
Cooler current	I_{cool}	-	-	-	1.2	A
Cooler voltage	V_{cool}	-	-	-	2.5	V
Polarization Maintaining Fiber Pigtail (Fujikura SM.15-P-8/125-UV/UV 400 PANDA or equivalent)						
Mode field diameter	$Ø_{mf}$	-	9.5	-	11.5	µm
Cladding diameter	$Ø_{cl}$	-	122	-	128	µm
Diameter of secondary coating	$Ø_{sc}$	-	380	-	420	µm
Diameter of Loose Tube	$Ø_{LT}$	-	0.8	-	1.0	mm
Length of Loose Tube	l_{LT}	-	0.9	-	-	m
Polarization extinction ratio	ER	E-field along slow axis	18	20	-	dB
Length of pigtail	l	-	1	-	-	m
Reliability						
Long term wavelength drift, see note 1	ML_λ	EOL: $\Delta\lambda$ = 0.2 nm	25	300	-	yr

1. Mechanical integrity/environmental endurance tested according to Telcordia GR-468-CORE and MIL-STD-883
   ML = Median Life, EOL = End Of Life.

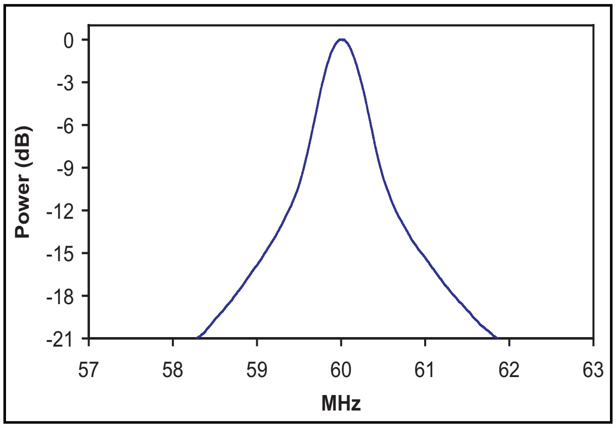
Typical Performance Characteristics



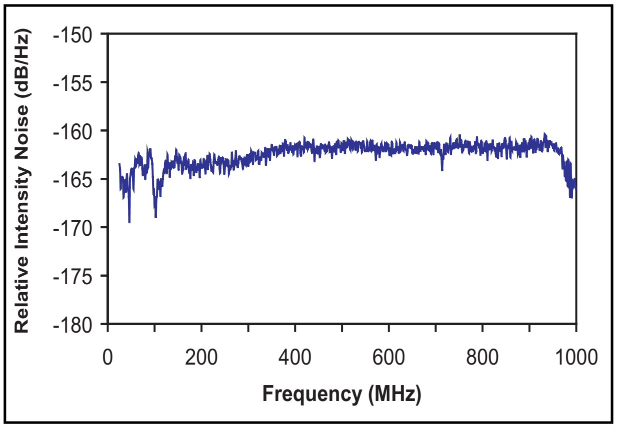
Typical L-I curve for the CQF935. Each laser is characterized at the temperature for which the specified wavelength channel λ_c is reached.



The use of multi-quantum well technology results in excellent side-mode suppression ratios and small linewidths. The inset shows how the wavelength is specified on each datasheet.



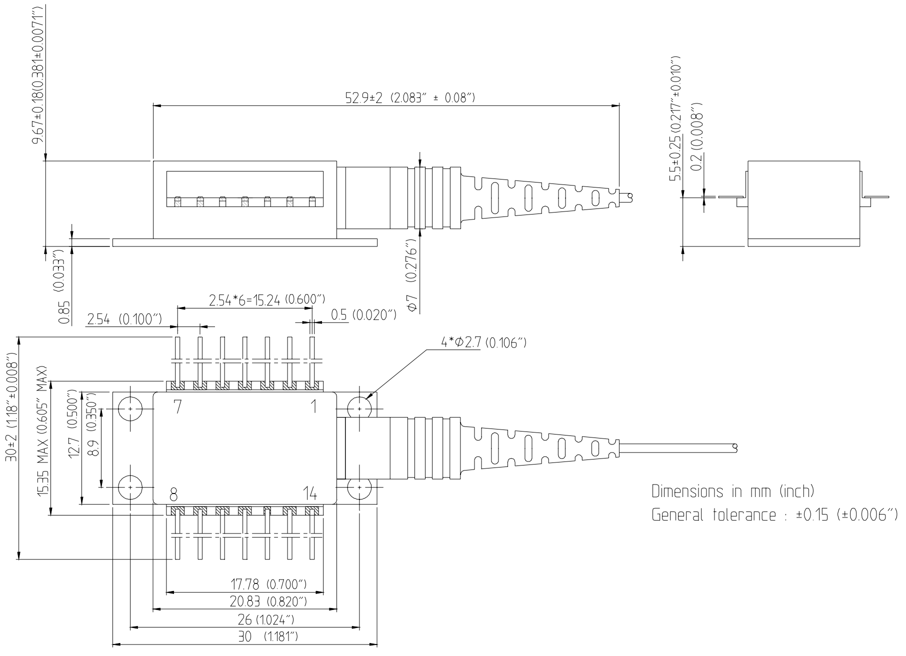
Linewidth at -3 dB is better than 1 MHz.



Relative intensity noise is better than -160 dB/Hz.

Mechanical Dimensions

Pinning	
1	thermistor
2	thermistor
3	LD cathode DC input via inductance
4	PD anode
5	PD cathode
6	cooler anode
7	cooler cathode
8	case GND
9	case GND
10	not connected
11	LD anode, case
12	LD cathode, AC input
13	LD anode, case
14	not connected



Ordering Information

Indicate your requirements by selecting one option from the configuration table. Please print the corresponding code in the available boxes to form your part number. For more information on this or other products and their availability, please contact your local JDS Uniphase account manager, call 800-871-8537 toll free in North America, or via e-mail at jdsu.sales@us.jdsuniphase.com. For contact information in Europe and Asia, please visit our Web site at www.jdsuniphase.com or call +1-800-8735-JDSU toll-free.

Sample: CQF935/708-19270 for wavelength 1555.75 nm.

Attention: Order confirmations on this part number will be preceeded by FG' (e.g., FG'CQF935/708-19270).2525

CQF935/708-□□□□□

JDSU Channel Code	Optical Frequency f_c (THz)	Wavelength (vacuum) λ_c (nm)	JDSU Channel Code	Optical Frequency f_c (THz)	Wavelength (vacuum) λ_c (nm)	JDSU Channel Code	Optical Frequency f_c (THz)	Wavelength (vacuum) λ_c (nm)
19630	196.30	1527.22	19290	192.90	1554.13	18950	189.50	1582.02
19620	196.20	1527.99	19280	192.80	1554.94	18940	189.40	1582.85
19610	196.10	1528.77	19270	192.70	1555.75	18930	189.30	1583.69
19600	196.00	1529.55	19260	192.60	1556.56	18920	189.20	1584.53
19590	195.90	1530.33	19250	192.50	1557.36	18910	189.10	1585.36
19580	195.80	1531.12	19240	192.40	1558.17	18900	189.00	1586.20
19570	195.70	1531.90	19230	192.30	1558.98	18890	188.90	1587.04
19560	195.60	1532.68	19220	192.20	1559.79	18880	188.80	1587.88
19550	195.50	1533.47	19210	192.10	1560.61	18870	188.70	1588.73
19540	195.40	1534.25	19200	192.00	1561.42	18860	188.60	1589.57
19530	195.30	1535.04	19190	191.90	1562.23	18850	188.50	1590.41
19520	195.20	1535.82	19180	191.80	1563.05	18840	188.40	1591.26
19510	195.10	1536.61	19170	191.70	1563.86	18830	188.30	1592.10
19500	195.00	1537.40	19160	191.60	1564.68	18820	188.20	1592.95
19490	194.90	1538.19	19150	191.50	1565.50	18810	188.10	1593.79
19480	194.80	1538.98	19140	191.40	1566.31	18800	188.00	1594.64
19470	194.70	1539.77	19130	191.30	1567.13	18790	187.90	1595.49
19460	194.60	1540.56	19120	191.20	1567.95	18780	187.80	1596.34
19450	194.50	1541.35	19110	191.10	1568.77	18770	187.70	1597.19
19440	194.40	1542.14	19100	191.00	1569.59	18760	187.60	1598.04
19430	194.30	1542.94	19090	190.90	1570.42	18750	187.50	1598.89
19420	194.20	1543.73	19080	190.80	1571.24	18740	187.40	1599.75
19410	194.10	1544.53	19070	190.70	1572.06	18730	187.30	1600.60
19400	194.00	1545.32	19060	190.60	1572.89	18720	187.20	1601.46
19390	193.90	1546.12	19050	190.50	1573.71	18710	187.10	1602.31
19380	193.80	1546.92	19040	190.40	1574.54	18700	187.00	1603.17
19370	193.70	1547.72	19030	190.30	1575.37	18690	186.90	1604.03
19360	193.60	1548.51	19020	190.20	1576.20	18680	186.80	1604.88
19350	193.50	1549.32	19010	190.10	1577.03	18670	186.70	1605.74
19340	193.40	1550.12	19000	190.00	1577.86	18660	186.60	1606.61
19330	193.30	1550.92	18990	189.90	1578.69	18650	186.50	1607.47
19320	193.20	1551.72	18980	189.80	1579.52	18640	186.40	1608.33
19310	193.10	1552.52	18970	189.70	1580.35	18630	186.30	1609.19
19300	193.00	1553.33	18960	189.60	1581.18	18620	186.20	1610.06

Fiber Termination: 1.25 mm or 2.5 mm ferrule.

PANDA is a trademark of Fujikura Ltd.
Telcordia is a trademark of Telcordia Technologies Incorporated

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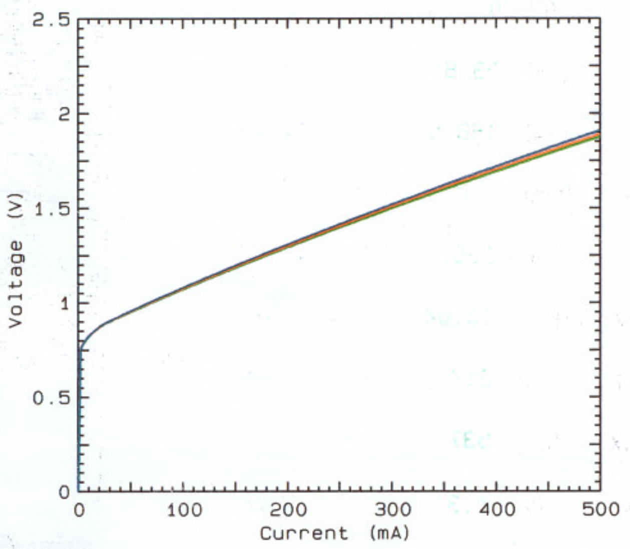
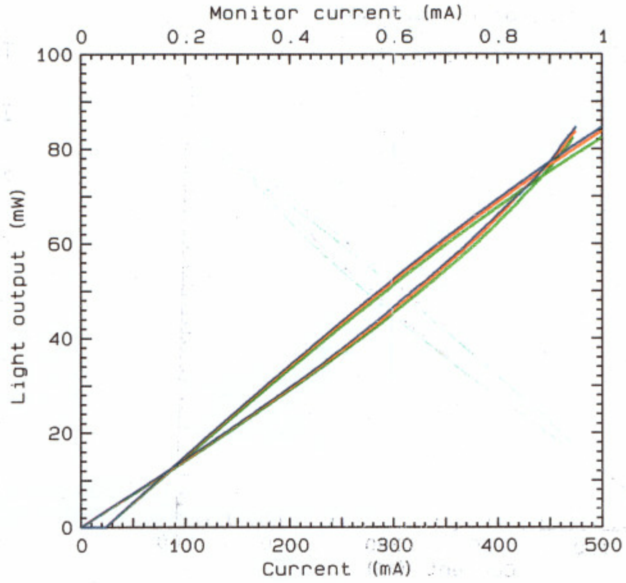
10131948 Rev.01 10/01

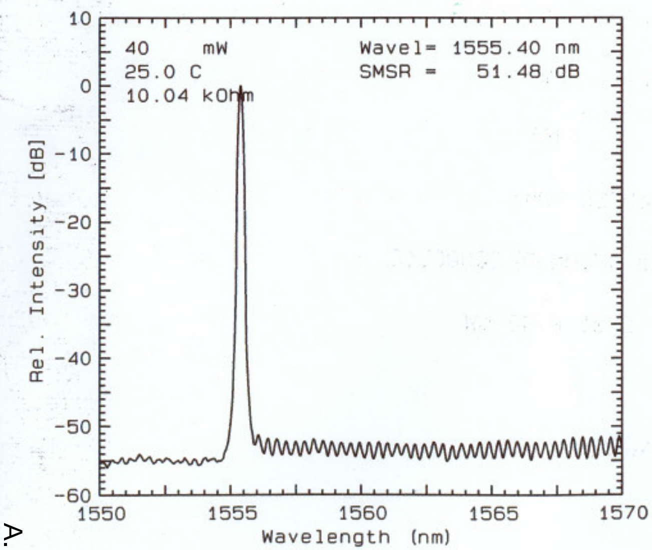
TEST DATA SHEET

CQF935/708-19270 # 190831

1550nm GaInAsP DFB-laserdiode with PM fibre pigtail







Temp	(C)	0	25	65
Ith	(mA)	23.8	23.9	23.7
Ec	(mW/A)	188.5	191.6	193.4
Rs	(Ohm)	2.4	2.4	2.5
Iop*	(mA)	235.2	231.8	230.4
Rntc*	(kOhm)	10.04	10.03	10.03
Ipelt*	(mA)	214	-88	-660
Imon*	(uA)	537	532	526
Vop*	(V)	1.37	1.36	1.37
Vpelt*	(V)	0.67	-0.19	-1.97
T.E.	(%)	-0.9	0.0	1.1
Wavel	(nm)		1555.742	
Top	(C)		25.0	
Rntc@25C kOhm			10.14	

Date (YYMMDD) 20020515

* : at P=40 mW

APPROVED BY :

UNIPHASE NETHERLANDS B.V. 15 May 2002 12: 46

LDM 4980 Series

Laser Diode Mounts

Product Features

- DIL, Butterfly, or connectorized package versions
- Easy insertion and removal of laser packages
- Configurable laser pin-out
- Standard laser current and temperature control connectors
- Bias-T modulation option (LDM-4982 and LDM-4984)
- Case temperature control option
- High speed modulation versions

The LDM-4980 Series of Laser Diode Mounts provides a compact, easy-to-use solution for laser diode fixturing. These mounts are available in DIL, butterfly and connectorized laser diode package versions. Butterfly versions are available for 7-pin, 13-pin, 14-pin, 20-pin and 26-pin packages. This series of mounts accommodates most telecom laser module types including CW, directly modulated (Bias-T), 2.5Gbits/s, 10Gbits/s, and tunable DFB laser modules.

Each mount features ILX Lightwave's standard 9-pin D-sub input connectors with configurable pin designations to accommodate virtually any laser diode pin configuration. Zero insertion force (ZIF) sockets, and spring-loaded clamps, facilitate ease of mounting. Bias-T options include a 50 Ω SMA input connector and circuitry for directly modulating the laser drive current.

New! LFS-498
Laser Fiber Spool

Compact, Convenient, and Flexible Laser Diode Mounts

ILX Lightwave
Photonic Test & Measurement Instrumentation

LDM 4980 Series

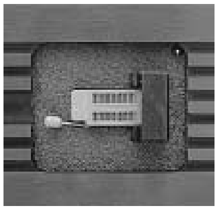
Laser Diode Mounts

The TE-550 Case Temperature Control option is available for all of these laser diode mounts. Case temperature control is ideal for applications requiring tight temperature stability, different case temperatures, or for testing laser diodes at a wider temperature range than can be accomplished with the module-internal TEC.

The LDM-4980 Series offers a high-value solution for demanding applications, such as laser diode testing and characterization, and are ideal for use with ILX Lightwave instrumentation.

Mounts for CW or Directly Modulated Lasers

LDM-4982 DIL Laser Mount



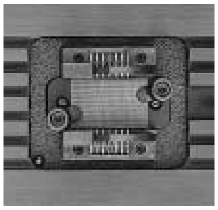
Dual-In-Line (DIL)

Compatible with 14-pin DIL and 8-pin mini–DIL laser modules, the LDM-4982 employs a zero insertion force (ZIF) socket for ease of use. This mount can be ordered with the Type-A Bias-T circuitry option.

ORDERING OPTIONS

TE-550 Case Temperature Control
BT-481 Bias-T Modulation Circuitry

LDM-4984 14-pin Butterfly Mount



14-Pin Butterfly

The LDM-4984 is compatible with 14-pin butterfly laser modules. Optionally, Bias-T circuits can be ordered with Type-A or Type-B configurations.

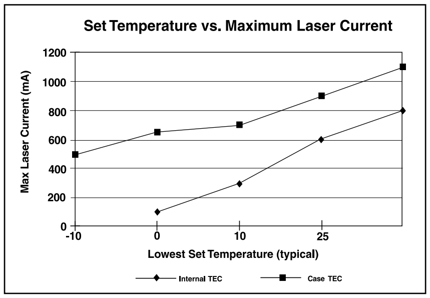
ORDERING OPTIONS

TE-550 Case Temperature Control
BT-482A Bias-T Modulation Circuitry
BT-482B Bias-T Modulation Circuitry

LDM-4986 Connectorized Laser Mount

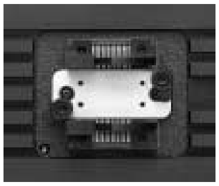
Connectorized (Flanged)

The LDM-4986 is compatible with 3-pin and 4-pin can-type and flanged lasers. Flanges can be clamped to the hotplate either vertically or horizontally. The TE-550 Case Temperature Control is standard on this mount.



The LDM-4980 Series Mounts stabilize temperature under a variety of load conditions.

LDM-4989 26-pin (and 20-pin) Butterfly Mount



26/20-Pin Butterfly

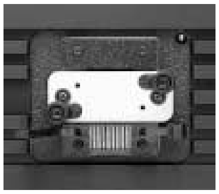
The LDM-4989 is designed for 20-pin and 26-pin butterfly packages, such as wavelength tunable DFB laser modules. Two standard 13-pin socket sides are used on this mount, enabling the use of most butterfly packages with standard pin–spacing. For example, on 20-pin packages with 7 pins on one side and 13 pins on the other side, every other mount pin is wired on the 7-pin side. Three 9-pin D-sub connector inputs are provided (1 female and 2 male) for use with user supplied custom cables.

ORDERING OPTIONS

LDM-4989T includes TE-550 Case Temperature Control (Note: LDM-4989T option reduces the number of input connector pins available for laser control to 18.)

Mounts for Internally Modulated Lasers

LDM-4983 13-pin (and 7-pin) Butterfly Mount



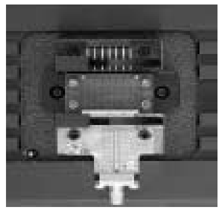
13/7-Pin 10 Gbits/s Package

The LDM-4983 is designed for "one-sided butterfly" packages that have the modulation input on one side, and seven or thirteen pins on the other side. These packages are typically used for 10 Gbits/s internally modulated laser modules. A special electrical terminal allows you to configure the potential of the hotplate and laser module case (grounded, floating, or at a specified potential).

ORDERING OPTIONS

LDM-4983T includes TE-550 Case Temperature Control

LDM-4984EA 14-pin Electroabsorption Modulated Laser Mount



14-Pin EA Modulated

The LDM-4984EA is compatible with the 14-pin butterfly electroabsorption modulated laser modules. The specially designed RF modulation input block interfaces a 50 Ω modulation source to internally–modulated lasers with a 50 Ω input impedance on pin 12. Pin configuration information is shown on the last page of this datasheet.

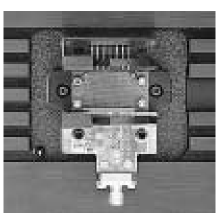
MODULATION SPECIFICATIONS[2]

Modulation Bandwidth:	10 MHz to >2.5 GHz
Flatness to 2.5GHz:	±1.5dB
Max Modulation Current:	140 mA rms
Input Connector:	50 Ω SMA
Laser Input Impedance:	50 Ω

ORDERING OPTIONS

TE-550 Case Temperature Control

LDM-4984RF 14-pin 2.5GHz Butterfly Mount



14-Pin Internal Bias-T Modulated

The LDM-4984RF is compatible with internal Bias-T modulated 14-pin butterfly laser modules. The specially designed RF modulation input block interfaces a 50 Ω modulation source to internally–modulated lasers with a 25 Ω input impedance on pin 12. A trim–capacitor is mounted on the RF block to optimize the modulation characteristics for your application. Pin configuration information is shown on the last page of this datasheet.

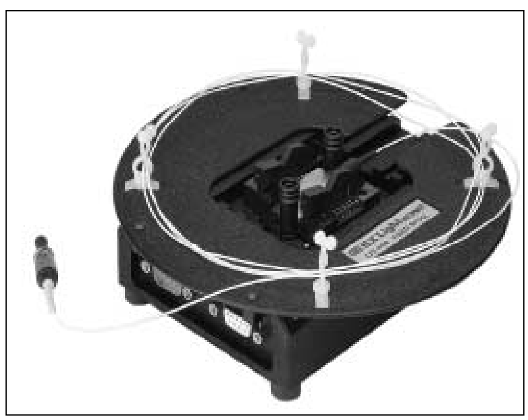
MODULATION SPECIFICATIONS[2]

Modulation Bandwidth:	10 MHz to >2.5 GHz
Flatness to 2.5 GHz:	±1.5 dB
Max. Modulation Current:	140 mA rms
Input Connector:	50 Ω SMA
Laser Input Impedance:	25 Ω

ORDERING OPTIONS

TE-550 Case Temperature Control

LFS-498 Laser Fiber Spool



The LFS-498 Fiber Management Spool

The LFS-498 is an innovative fiber management tool compatible with all the LDM-4980 Series Laser Diode Mounts. The LFS-498 effortlessly attaches to the top of the laser diode mount, organizing your benchtop or test station and prevents inadvertant fiber damage.

ORDERING INFORMATION

LFS-498 Laser Fiber Spool

LDM 4980 Series

Laser Diode Mounts

Specifications

INPUT CONNECTORS (EXCEPT LDM-4989)

1) Laser Diode Current (Female 9-pin)
2) Internal Laser Temp Control (Male 9-pin)
3) Mount Temperature Control Option (Male 9-pin)

The LDM–4989 has three 9-pin connectors which are completely user–configurable.

CASE TEMPERATURE CONTROL OPTION

Temperature Control Range:[1]	–5°C to 50°C
Sensor Type:	10 kΩ thermistor
TE Module Ratings:	Q_{max} = 14 W
	I_{max} = 6.0 A
	V_{max} = 4.2 V
	DT_{max} = 70°C
Size:	Adds approx. 1.5" to width and 0.3" to height

BIAS-T OPTION[2]

Modulation Bandwidth:	10–800 MHz
Input Impedance:	50 Ω
Connector:	SMA

GENERAL

Size (HxWxD):	31.8 mm x 102 mm x 140 mm 1.25" x 4.0" x 5.5"
Weight:	0.64 kg (1.4 lbs)

NOTES

1 Typical temperature control range at 20°C ambient. Actual range will depend on thermal power from laser module, ambient temperature and whether or not the mount is affixed to optical table (¼–20 screws included with TE-550 option.)

2 Actual optical modulation bandwidth and flatness are dependent upon laser used.

ORDERING INFORMATION

LDM-4982	**DIL Laser Mount**
TE-550	Case Temperature Control
BT-481	Bias-T Modulation Circuitry
LDM-4984	**14-pin Butterfly Mount**
TE-550	Case Temperature Control
BT-482A	Bias-T Modulation Circuitry
BT-482B	Bias-T Modulation Circuitry
LDM-4986	**Connectorized Laser Mount**
LDM-4989	**26-pin and 20-pin Butterfly Mount**
LDM-4989T	Includes TE-550 Case Temperature Control
LDM-4983	**13-pin and 7-pin Butterfly Mount**
LDM-4983T	Includes TE-550 Case Temperature Control
LDM-4984EA	**14-pin Electroabsorption Modulated Laser Mount**
TE-550	Case Temperature Control
LDM-4984RF	**14-pin 2.5 GHz Butterfly Mount**
TE-550	Case Temperature Control
LFS-498	**Laser Fiber Spool**

Bias–T and 2.5Gbits/s Pin Configuration Guide

Circuit Type	Type A Bias–T		Type B Bias–T	2.5Gbits/s Internally Modulated Lasers	
Package Type	DIL	Butterfly	Butterfly	Butterfly–RF	Butterfly–EA
Mount Option	BT481	BT482A	BT482B	LDM–4984RF	LDM–4984EA
PIN 1	*	*	*	*	*
PIN 2	*	*	*	*	*
PIN 3	*	*	*	*	*
PIN 4	*	*	*	*	*
PIN 5	*	*	*	*	*
PIN 6	*	*	*	*	*
PIN 7	*	*	*	*	*
PIN 8	*	*	*	Las Anode/Case	Las Cathode/Case
PIN 9	Laser Cathode		*	Las Anode/Case	Las Cathode/Case
PIN 10	Las Anode/Case		Las Anode/Case	Las Anode/Case	Las Cathode/Case
PIN 11	*	*	Laser Cathode	Las Anode/Case	Las Cathode/Case
PIN 12	*	*	*	Modulation (AC in)	Modulation (AC in)
PIN 13	*	*	*	Las Anode/Case	Las Cathode/Case
PIN 14	*	*	*	Las Anode/Case	Las Cathode/Case

* User configurable pin assignment. All pins are configurable on other mount versions.

ILX Lightwave
Photonic Test & Measurement Instrumentation
P.O. Box 6310, Bozeman, MT 59771• FAX: 406-586-9405
www.ilxlightwave.com

For information call
1-800-459-9459
International Inquiries: 406-586-1244
email: sales@ilxlightwave.com

OEM

LDX-3100
Laser Diode
Current Source

LDT-5100
Temperature
Controller

Product Features

LDX-3100 Current Source
0 to 250 mA output range

Low noise, High stability

Constant current and constant power control modes

Slow-turn-on circuit for laser diode protection

Mounts to LDT-5100 TE Controller for complete OEM laser diode control

LDT-5100 Temperature Controller
High stability (within 0.005°C)

Low-noise, Bipolar control

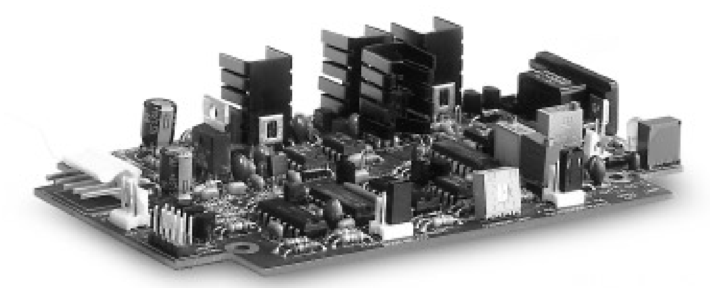
Fast settling time with hybrid P-I control loop

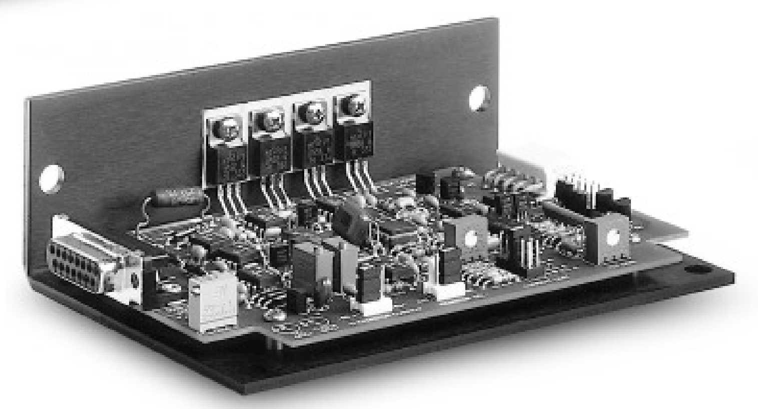
TE module current limit
Integrated heat-sink / mounting plate

Designed to compliment ILX Lightwave's line of precision laser diode instrumentation, the LDX-3100 and LDT-5100 offer precise low-noise, high-stability current and temperature control of laser diodes to meet the needs of critical OEM and other space-constrained applications.

The LDX-3100 laser diode current source provides the flexibility of a mountable circuit board with laboratory-grade performance and proven laser protection. It can be operated in constant current or constant power modes. Similarly, the LDT-5100 thermoelectric temperature controller provides outstanding temperature stabilization of laser diodes or photodetectors.

The products can be used together or independently and are easily incorporated into other products with demanding laser diode drive requirements. Both are based on ILX Lightwave's proven circuit topologies, and are pin-compatible with ILX Lightwave laboratory instruments and laser mounts.





Board-level laser diode current & TE control for demanding applications.

ILX Lightwave
Photonic Test & Measurement Instrumentation

OEM
LDX-3100
Laser Diode
Current Source
LDT-5100
Temperature
Controller

LDC-3100 Specifications

Board-level laser current control

The LDX-3100 Current Source is a board-level device which, when powered by the appropriate supply, delivers stable, low-noise current. The LDX-3100 is optimized to drive laser diodes and LED's with an output range of 0 to 250 mA, with a compliance voltage >5.5 V.

Two operating modes for flexibility

The LDX-3100 can be operated in one of two modes. In constant current mode, a stable current can be adjusted from an on-board trimpot or through an external control voltage. The output can be modulated up to 2 kHz, so it's easy to dither the laser current and power and wavelength tuning. In constant power mode, the photocurrent from the laser's rear-facet monitor is used in a feedback control loop to the laser drive current to maintain stable laser output power, even if temperature changes.

Proven ILX Lightwave performance

The circuit topology of the LDX-3100 Laser Diode Current Source is based on ILX Lightwave's LDX-3412 Current Source, which is designed for laboratory benchtop applications. For more information about the LDX-3412, call a technical sales engineer at ILX Lightwave.

For more information about laser diodes and driving them safely, please request the followingILX Lightwave Application Notes:

Application Notes #3:
Protecting your Laser Diode

Application Notes #5:
An Overview of Laser Diode Characteristics

Application Notes #7:
Using Laser Diodes in Atomic Physics

Application Notes #8:
Mode-Hopping in Semiconductor Lasers

LDX-3100 OEM Laser Diode Current Source

INPUTS

Power Supply:	12–18 V @ 350 mA -12 to -18 V @ 50 mA
Control:	Output On (Default) when power supplied. User can control output on/off with TTL line
Isolated Control:[2]	TTL Signal (VCC required)
Mode Select[3]	
Jumper Selectable:	Constant I / Constant I_{PD}
I Set:	
1) External Voltage:	(0-5 V, 50 mA/V)
Bandwidth[4]:	2 kHz
2) Internal:	25-turn pot
I Limit Set:	1-turn pot adjustable, 0 to 250 mA (min.)
Photodiode Feedback Type:	Differential, zero-bias
Photodiode Range:	20 µA to 2 mA
Stability[5]:	±0.1%

OUTPUTS

Laser Output	
Current:	0–250 mA (min.)
Compliance Voltage:	>5.5 V
Temp. Coeffecient:	<50 ppm/°C
Short Term Stability (1 hr.):	<50 ppm
Long Term Stability (24 hr.):	<100 ppm
Control Transients[6]:	<100 µA
Noise (rms):	<2 µA
Laser Current Measurement:	0–5 V buffered output
Transfer Function:	50 mA/V
Accuracy:	±0.1% of FS (±0.25 mA)
Photodiode I Measurement:	0–5 V buffered output
Transfer Function:	0.4 mA/V
Accuracy:	±0.1% of FS (±2 µA)
Limit Current Measurement:	0–5 V buffered output
Transfer Function:	50 mA/V
Accuracy:	±1.5% of FS (±3.75 mA)

Laser Diode Protection	
ESD:	JFET (Normally closed) shorting output
Power:	Current Supply regulated onboard, overvoltage protection, transient suppression.
Indicators	
Power On:	Green LED
Current On:	Pads for ext. LED (10 mA)
Error (open circuit):	Pads for ext. LED (10 mA)

GENERAL

Size:	12 mm x 88 mm x 139 mm 0.5"x 3.5"x 5.5" (Printed Circuit Board — includes four 1.25" mounting standoffs)
Operating Temperature:	0°C–50°C
Storage Temperature:	-40°C to 70°C
Recommended Power Supplies:	Tektronix® PS280 ELPAC® WM113 or WM220-1

NOTES

1. All values measured after a one-hour warm-up period.
2. Isolated control is provided to turn output off and ondepending on input (such as TEC error status from LDT-5100). No connection disables this control.
3. Mode may be changed only when output is off.
4. In constant power mode, The bandwidth is reduced to approximately 200 Hz, depending on the photodiode used.
5. Maximum monitor photodiode drift over 30 min. period, after warm up. Assumes zero drift in responsivity of photodiode.
6. Maximum output current transient generated from normal operational (ON/OFF) situations.

ORDERING INFORMATION

LDX-3100	OEM Current Source
CC-305S	Current Source/Laser Diode Mount Interconnect Cable
CC-306S	Current Source/Unterminated Interconnect Cable
CC-350	Power Supply Adaptor Cable (For use when integrating current source board into finished equipment requiring external connection)
LNF-320	Low Noise Filter (ELPAC WM113 & WM220-1)

LDT-5100 Specifications

Superior temperature stability

The LDT-5100 Temperature Controller is a board-level device which, when powered by the appropriate supply, maintains highly stable temperature of a laser diode or photodetector.

Using the resistance of a temperature-dependent thermistor as feedback, it stabilizes temperature by driving current to a thermoelectric (TE) module. The TE drive of the LDT-5100 is bipolar, allowing for highly stable temperatures and fast settling times. Desired temperature (thermistor resistance) is set by adjusting an on-board trimpot or by connecting an external reference resistor (for a more precise set-point).

Proven design platform

The circuit topology of the LDT-5100 Board-Level Temperature Controller is based on ILX Lightwave's LDT-5412 Temperature Controller, which is designed for laboratory benchtop applications. For more information about the LDT-5412 call an ILX Lightwave sales engineer.

For more information about controlling temperature with thermoelectric (Peltier) modules, please request the following Application Notes:

Application Notes #1:
Controlling Temperature of Diode Lasers and Detectors Thermoelectrically

Application Notes #2:
Selecting and Using Thermistors for Temperature Control

LDT-5100 OEM Laser Diode TE Controller

INPUTS

Power Supply Input:	±12 to 18 V @ 75 mA[2] +4.5 to 7 V @ 2 A[3]	
Control:	Output On (Default) when power supplied. User can control output on/off with TTL line. (Low = output Off)	
Thermistor R Setting[4]:		
Jumper Selectable int./ext. R_{set}:		
1) External R_{set}	- Thermistor R driven to match reference precision resistor across connector pins 5, 6.	
2) Internal R_{set}	- 50 kΩ adjustable 10-turn pot	
Thermistor Current:	Jumper selectable 10 µA/100 µA	
I_{TE} Limit:		
Jumper Selectable:	250 mA, 500 mA, 1 A, 1.5 A, 2 A	
Limit Accuracy:	± 50 mA	
TEC Gain:	1 to 50 - adjustable 1-turn pot	

OUTPUT

Output Type:	Bipolar, floating, constant current source	
Current Range:	-2 A to 2 A	
Compliance Voltage:	>2 VDC	
	Internal R set (pot)	External R set (resistor)
Stability (24 hr.)[5]:	±0.01°C	±0.005°C
Temperature Coefficient:	0.01°C/°C (ambient)	0.005°C/°C (ambient)
Actual R Measurement:	(Buffered output voltage: 0-5 V)	
	100 µA range	10 µA range
Transfer Function:	10 kΩ/V	100 kΩ/V
Accuracy:	±50 Ω	±500 Ω
Actual I_{TE} Measurement:		
Buffered Output Voltage:	-5 V to +5 V	
Transfer Function:	400 mA/V	
Accuracy:	±40 mA	
LED Indicators:		
Output On:	PCB pads for external LED (10 mA), and open-collector output	
TEC Open Error:	PCB pads for external LED (10 mA), and open collector output[6]	
Sensor Open Error:	PCB pads for external LED (10 mA), and open-collector output[6]	

GENERAL

Size:	44 mm x 95 mm x 139 mm 1.75" x 3.75" x 5.5" (Printed circuit board with integrated heat-sink / mounting bracket.)
Weight:	8.75 oz.
Operating Temperature:	0°C–50°C
Storage Temperature:	-40°C to 70°C
Recommended Power Supplies:	Tektronix® PS280, ELPAC® WM220-1

NOTES

1. All values tested after a one-hour warm-up period.
2. Additional current is needed if external LED indicators are used (approx. 10 mA per LED)
3. Higher voltage allowed with use of additional heat-sinking of mounting plate.
4. Use of an external precision resistor is the recommended method to set desired thermistor R.
5. Over any 24 hr. Period, controlling an LDM-4412 mount @ 25°C, with a 10 kΩ thermistor, on 100 µA setting.
6. Open-collector outputs for TEC error and sensor error can be used to control other functions such as laser output disable line on the LDX-3100 current source.

ORDERING INFORMATION

LDT-5100	OEM Thermoelectric Temperature Controller (2 A, 4 W) (includes heat sink / L-Bracket Mount)
CC-350	Power Supply Adaptor Cable (For use when integrating temperature control board into finished equipment requiring external connection)
CC-501S	TE Controller/Unterminated Cable
CC-505S	TE Controller/Laser Diode Mount Interconnect Cable

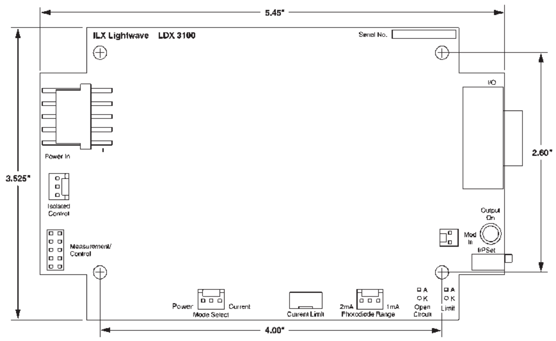
OEM

LDX-3100
Laser Diode Current Source

LDT-5100
Temperature Controller

Specifications

LDX-3100 Current Source



The LDX-3100 includes four 1.25" standoffs, and may be mounted to the LDT-5100

LDX-3100 Connectors

Laser Current, Photodiode, I/O Connector:

9-pin, standard D-sub

- 1,2 Safety Interlock
- 3 N/C
- 4,5 Laser Diode Cathode (-)
- 6 Photodiode (cathode)
- 7 Photodiode (anode)
- 8,9 Laser Diode Anode (+)

Measurement/ Control Connector:

10-pin, 0.1" centers, IDC-compatible

- 1 Output on
- 2 Output status
- 3 +5 V
- 4 Open circuit error
- 5 Ground
- 6 Photodiode current monitor
- 7 Limit sense
- 8 Limit current monitor
- 9 Ground
- 10 Laser current monitor

Power Input Connector:

5-pin, Right-angle, 0.156" centers

- 1 N/C
- 2 GND
- 3 -15 VDC
- 4 GND
- 5 +15 VDC

Modulation Input Connector:

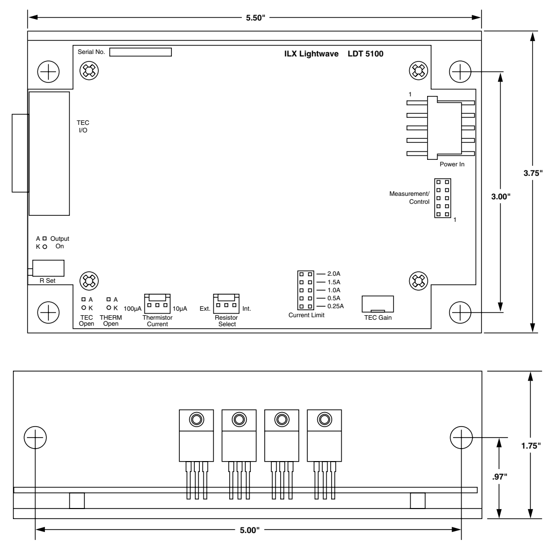
2-pin, 0.1" centers

Isolated Control Connector:

3-pin, 0.1" centers

- 1 ISO VCC
- 2 N/C
- 3 ISO CTRL

LDT-5100 Temperature Controller



The LDT-5100 includes a heat sink mounting bracket.

LDT-5100 Connectors

TEC Connector:

15-pin D-sub

- 1,2 TE Module +
- 3,4 TE Module -
- 5,6 External Reference Resistor
- 7 Thermistor +
- 8 Thermistor -
- 9 Analog Ground
- 10 Control Signal (provides 1V/A to drive booster supplies)
- 11-15 N/C

Power Input Connector:

5-pin, Right-angle, 0.156" centers

- 1 +TE Supply (+4.5 to 7 VDC @ 2 A)
- 2 GND
- 3 -15 VDC
- 4 GND
- 5 +15 VDC

Measurement/ Control Connector:

10-pin, 0.1" centers, IDC-compatible

- 1 Output off (input)
- 2 Output on indication (open-collector output)
- 3 N/C
- 4 TEC open error (open-collector output)
- 5 N/C
- 6 Thermistor open error (open-collector output)
- 7 N/C
- 8 TE current monitor
- 9 N/C
- 10 Actual R monitor

In keeping with our commitment to continuing improvement, ILX Lightwave reserves the right to change specifications without notice and without liability for such changes.

ILX Lightwave
Photonic Test & Measurement Instrumentation
P.O. Box 6310, Bozeman, MT 59771• FAX: 406-586-9405
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For information call
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International Inquiries: 406-586-1244
email: sales@ilxlightwave.com

JDS Uniphase

Product Bulletin

APE™ Microwave Analog Intensity Modulator

This high performance analog modulator is designed for use in microwave fiberoptic links that operate at frequencies to 20 GHz and beyond.

APE optical waveguides and velocity matched transmission line technology are combined in a modulator that offers high power, low loss optical characteristics, and high modulation efficiency.

APE microwave analog intensity modulators are available for operation at wavelengths of 1300 nm and 1550 nm.

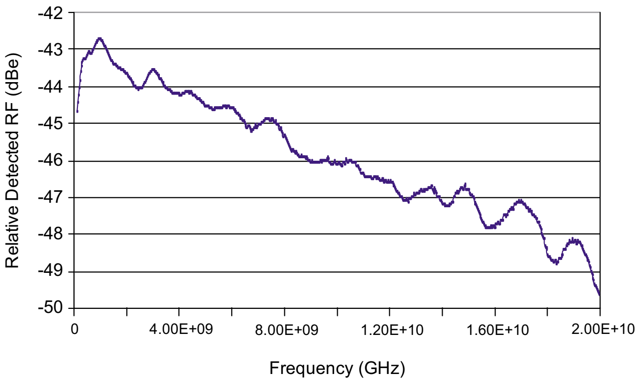
Key Features

- Low drive voltage
- Direct current (DC) to 20 GHz operation
- Low optical insertion loss
- High optical power operation
- 1300 nm and 1550 nm models

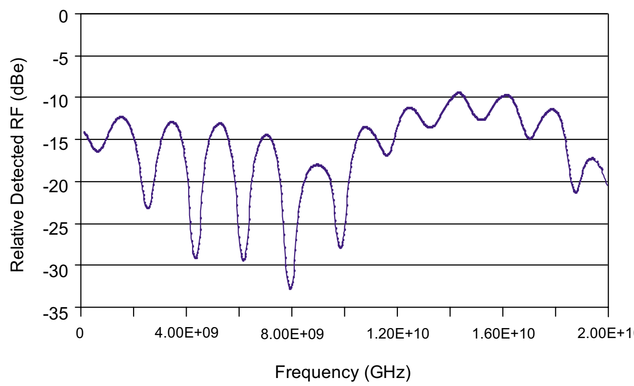
Applications

- Antenna remoting
- Short pulse experimentation

Typical Frequency Response, S21



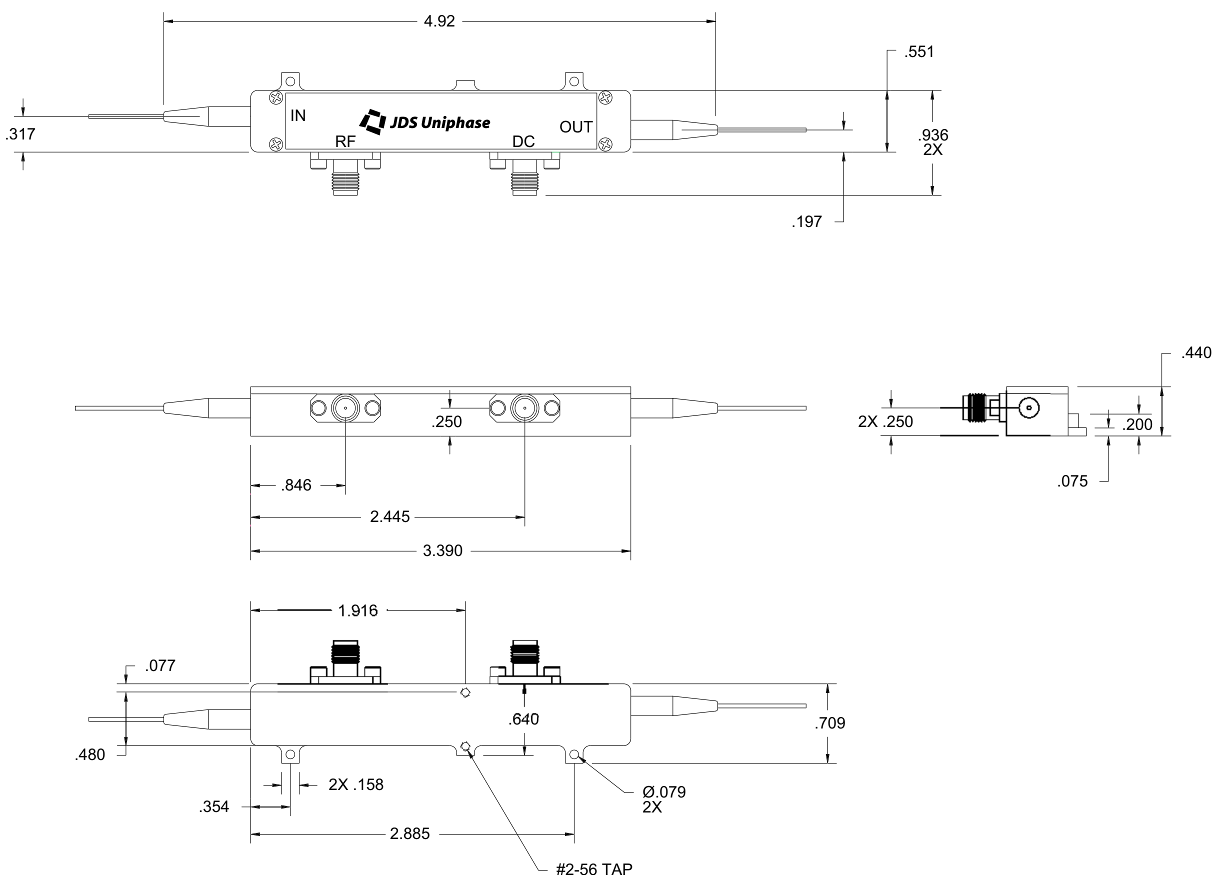
Typical Return Loss Curve, S11



S21 Roll-Off Relative to 130 MHz

Frequency (GHz)	Maximum (dBe)
0.13	0
3	-1
5	-2
9	-3
12	-4.5
18	-6
20	-7

APE™ Microwave Analog Intensity ModulatorPackage Dimensions (Specifications in inches unless otherwise noted.)



Specifications

Parameter			
Description		**AM-130**	**AM-150**
Optical (note[1])			
Operating wavelength	Minimum	1320±10 nm	1550±10 nm
Insertion loss (note[2])	Maximum	5.0 dB	
On/off extinction ratio	Minimum	20 dB	
Optical return loss	Maximum	-45 dB	
Electrical (note[1])			
RF port			
RF input power	Maximum	27 dBm	
Vπ at 1 GHz (note[3])	Maximum	5.5 V	6.0 V
Impedance	Typical	50 Ω	
Bias port			
Vπ at DC	Maximum	10.5 V	12 V
Impedance		>100 kΩ	
Deviation from quadrature (note[4])		±1 V	
General			
Material		Lithium niobate	
Crystal orientation		X-cut, y-propagating	
Mechanical			
Input optical power	Maximum	200 mW	
Electrical connectors (package)		SMA connectors	
Fibers			
1320 nm device, PM input		Fujikura SM 13-P-7/125-UV/UV-100	
1320 nm device, SM output		SMF-28	
1550 nm device, PM input		Fujikura SM 15-P-8/125-UV/UV-100	
1550 nm device, SM output		SMF-28	
Environmental			
Operating temperature		0 to 70 °C	
Storage temperature		-40 to 85 °C	

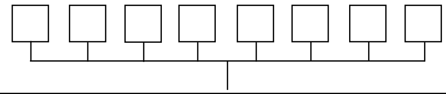
Note: Specifications are subject to change without notice. All device specifications are at room temperature and at beginning of life. These devices are offered as limited production models. Telcordia qualification of this device is not planned at this time.

1. All measurements made at 23°C unless otherwise noted.
2. Optical loss is measured at the maximum of the modulator's transfer function and does not include the 3 dB loss incurred when operated at quadrature.
3. Vπ is specified at the modulator. Pπ is the power required to generate Vπ/2 at the connector.
4. Optimum distortion performance may require bias control.

Ordering Information

For more information on this or other products and their availability, please contact your local JDS Uniphase account manager or JDS Uniphase directly at 800-871-8537 in North America and 800-8735-5378 worldwide or via e-mail at jdsu.sales@jdsu.com.

Sample: 10022054



Product Code	Description
10022054	1310 nm, no optical connectors
10020461	1310 nm, FC/PC optical connectors
10020462	1550 nm, no optical connectors
10020465	1550 nm, FC/PC optical connectors

SMF-28, Fujikura SM 13-P-7/125-UV/UV-100, and Fujikura SM 15-P-8/125-UV/UV-100 are registered trademarks of Corning Incorporated.

JDS Uniphase

North America toll-free: 800-871-8537
Worldwide toll-free: 800-8735-5378
www.jdsu.com

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10131957 Rev. 002 03/02

Discovery Semiconductors, Inc.
"We Chip the Future"

DSC-R401ER
Low-Noise 12.3 Gbits/s Optical Receiver for RZ data

Description:

The 20 GHz bandwidth of the R401ER preserves the Return to Zero (RZ) pulse shape while providing up to 2 V_{p-p} output for OC-192/SDH-64 data. To meet the transmission distances required in the long-haul networks, designers of 10 Gbits/s transport systems need extra bandwidth for Forward Error Correction (FEC) and RZ digital formats. The low-noise amplifier provides gain to drive circuit board with low electrical return loss, improving link performance, consistency and reliability while saving board space.

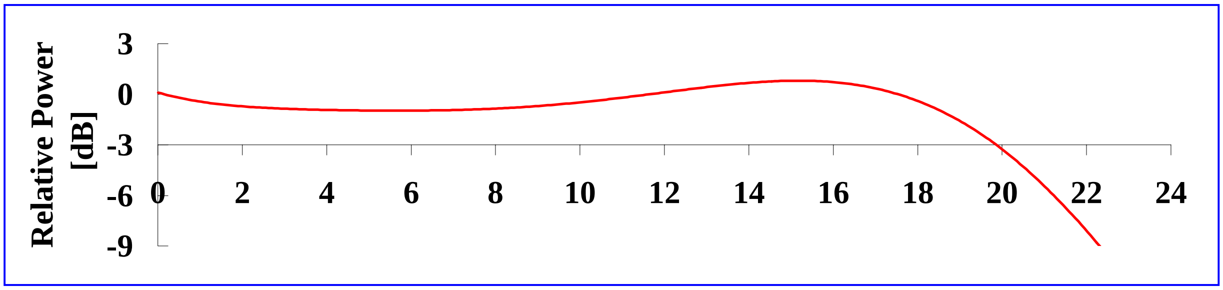
Features:

Wide bandwidth for 10.8 and 12.3 Gbits/s data in RZ format
Low electrical return loss
Low group delays
Conversion Gain of 35V/W @ 1550 nm
Low-Noise and Wide-Bandwidth
Small Footprint Miniature Package
Hermetically Sealed and Built to GR-468 Standards

Applications:

Digital Receiver for OC-192/SDH-64 Telecom and Datacom

Typical Frequency Response Curve



Specifications:

Parameter	Min.	Typ.	Max.	Units
Responsivity @ 1.55um	0.6	0.7		A/W
Conversion Gain @ 1.55um	30	35		V/W
Power Gain	8	9	10	dB
Equiv. Transimpedance	40	50		Ω
Gain Flatness		+/-2		dB
Bandwidth (1.55 um)	18	20		GHz
Lower Limit		50		kHz
Noise		15	20	pA/√Hz
Bias Voltage Amp	+4.5	+5	+5.5	V
Bias Voltage PIN	+3	+5	+10	V
Power Dissipation		300		mW@5V
Electrical Return Loss	10	15		dB
Optical Return Loss	30	35		dB
Wavelength response	0.8		1.6	um

Options:

Optical Input:

Pigtail:	1 m Single or Multi-Mode fiber
Fiber buffer:	3 mm std. Opt.:0.9 mm buffer dia.
Connector:	FC, SC, ST, others by request
Finish:	UPC, APC

RF Output:

Connector:	K, female std., male option
Coupling:	50 kHz std.

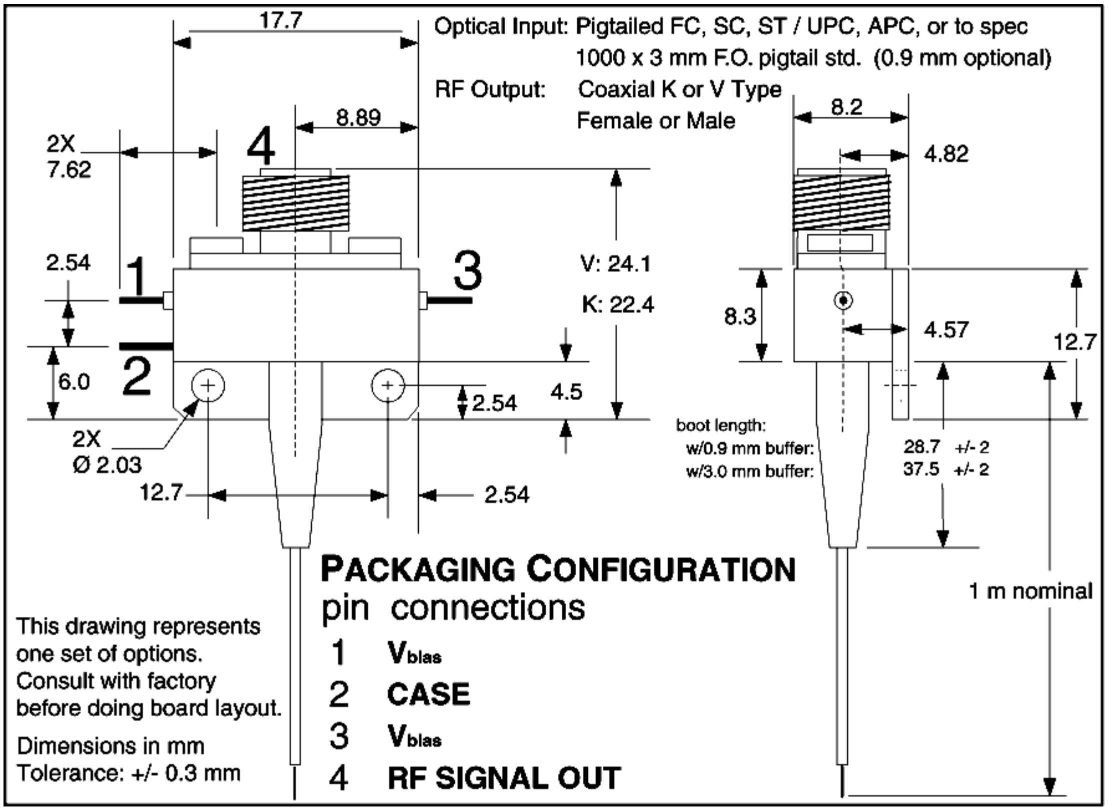
R401ERe 0110

119 Silvia Street, Ewing, NJ 08628 USA
Phone: (609) 434-1311 Fax: (609) 434-1317 www.chipsat.com sales@chipsat.com

Specifications are subject to change without notice.

. 2001 Discovery Semiconductors, Inc.

PACKAGING CONFIGURATION for R401ER



Specifications are subject to change without notice.

PIN 1: + 5 Volts
PIN 3: + 5 to 10 Volts

119 Silvia Street, Ewing, NJ 08628 USA
Phone: (609) 434-1311 Fax: (609) 434-1317 www.chipsat.com sales@chipsat.com

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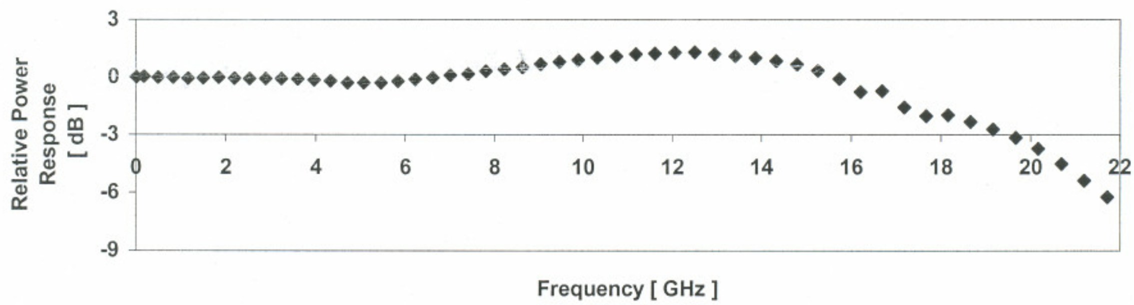
186 Princeton-Hightstown Rd, Princeton Jct. NJ 08550
Tel: (609) 275-8667, Fax: (609) 275-0872
An ISO 9001:2000 Certified Company

Test Data Report

		Date:	7/26/02
Customer:	AF Rome Laboratory	PO :	F30602-02-P-0088
Part number:	DSC-R401ER-33-FC/UPC-K	WO :	1321
Description:	InGaAs Optical Receiver	Serial number:	**610156**
Tested by:	Meilian Qiu	Witnessed by:	[signature]

Parameter	Specification	Measured Value	Units
-3dB Bandwidth @ V_{bd} = + 5 V & V_{dd} = + 5 V	18	19.5	GHz
Coupled conversion gain at 1550 nm	Min: 30	>30	V/W
Detector dark current at + 5 V	Max: 100	13	nA
Optical Return Loss at 1550 nm	Min: 30	39	dB

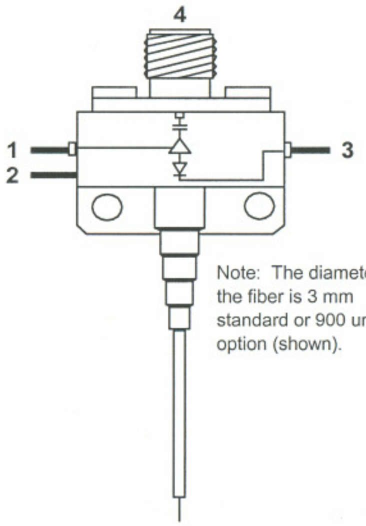


Remarks:
(1) Please see the package diagram on the right for pin connections.
Pin 1: V_{dd} = + 5 V @ ~ 55 mA & Pin 3: V_{bd} = + 5 V @ < 100 nA*
Nominal Low Frequency –3 dB (50 KHz.)

* Leakage current at room temperature without laser on.

Pin Connections:

Pin# 1.	Bias Voltage Amplifier (V_{dd})
2.	Case Ground
3.	Bias Voltage Photodiode (V_{bd})
4.	RF Signal Out



Note: The diameter of the fiber is 3 mm standard or 900 um option (shown).

Observe Polarities
Please connect in the following order, and disconnect in the reverse order:
(1) Grounding (2) V_{bd} (3) V_{dd}

Certificate ID: NJ-03-01-02
EAC/SJC/NAJCS
Code: 19/3669 3674/33441

RvC Accredited by the RvA

MDD FIBER OPTIC LINK

ELECTRICAL SPECIFICATIONS (-30 dBm input power, 1 m of fiber)

PARAMETER	CONDITIONS	UNITS	MIN.	TYP.	MAX.
Bandwidth	3 dB	GHz	0.1		11
Gain	Option 1	dB	15	18	25
	Option 2	dB	0	5	10
Noise Figure	Option 1	dB		15	20
	Option 2	dB		15	23
Group Delay	peak to peak	ns			0.1
VSWR	input / output				2.0:1
Phase Noise	100 Hz offset	dBc		100	
Input Power at 1 dB Compression	Option 1	dBm		-20	
	Option 2	dBm		-5	
Spurious Free Dynamic Range	1 MHz Bandwidth	dBm	57		
Minimum Input Power		dBm			
Maximum Input Power	No Damage	dBm			+5
Maximum Output Power		dBm			+10
RF Connectors	SMA Female				
Impedence	input / output	ohms		50	

Optical Specifications		UNITS	MIN.	TYP.	MAX.
Fiber (core/cladding)	Single Mode Fiber				
Fiber optic connectors	E-2000 m/APC				
Wavelength		nm	1540	1550	1560
Spectral Width		nm			1
Optical Power in Fiber	reference only	mW	3	6	9
Side Mode Suppression Ratio		dB	37		

POWER REQUIREMENTS	Typical Current at 25°C baseplate		Min	TYP.	Max
Transmitter	300 mA		+10	+12 V	+15
	15 mA		-10	-12 V	-15
	325 mA*		+3	+4 V	+6
Receiver	180 mA		+10	+12 V	+15

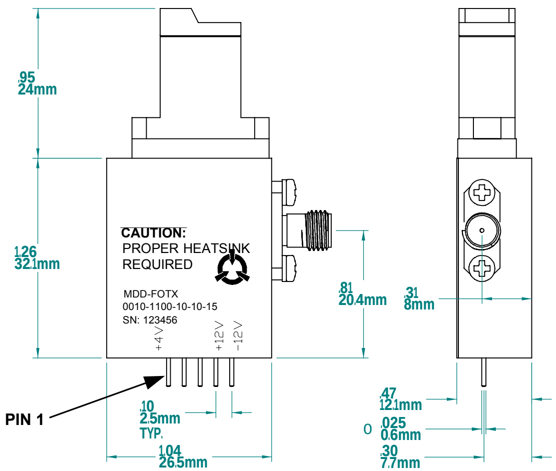
* 1.2 A at maximum laser cooling

GENERAL SPECIFICATIONS	CONDITIONS	UNITS	MIN.	TYP.	MAX.
Operating temperature		°C	-20		+45
Storage temperature		°C	-40		+85
Humidity	relative humidity, non-condensing	%			95

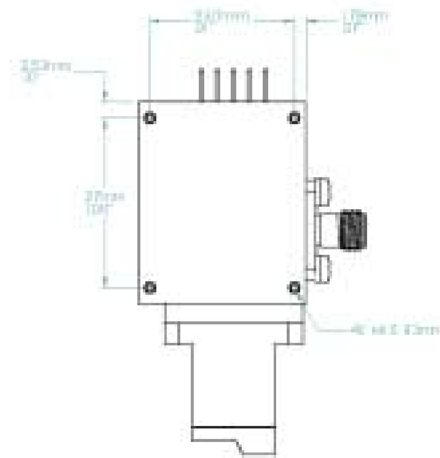
100 DAVIDS DRIVE, HAUPPAUGE NY 11788
PHONE 631-436-7400, FAX 631-439-9354

MDD

FIBER OPTIC LINK



MOUNTING HOLE LOCATIONS



RF INPUT CONNECTOR: SMA
OPTICAL CONNECTOR: DIAMOND E-2000
OPTICAL FIBER: SINGLE MODE

TRANSMITTER POWER SUPPLY

PIN	VOLTAGE	CURRENT (AMPS)	NOTES
1	+4	0.325	@ 25°C BASE PLATE TEMP.
		1.2	FOR MAXIMUM LASER COOLING
2	N/C		
3	N/C		
4	+12	0.3	
5	-12	0.013	

APPLY ALL VOLTAGES SIMULTANEOUSLY OR IN THE FOLLOWING ORDER:
1. +4V
2. -12V
3. +12V

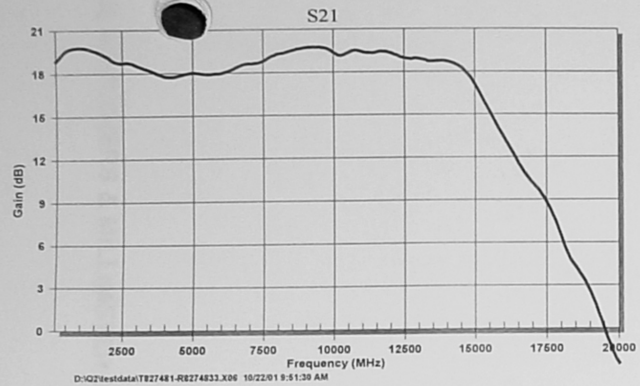
NOTE:

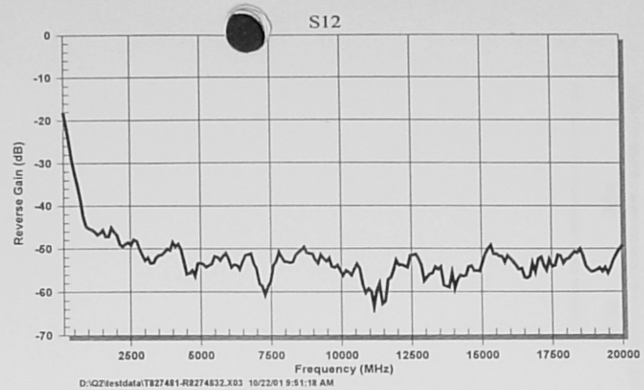
ALLOW 2 MINUTES FOR LASER TEMPERATURE STABILIZATION AFTER APPLYING POWER.

PIN	VOLTAGE	CURRENT (AMPS)	NOTES
1	N/C		
2	N/C		
3	N/C		
4	+12	0.18	
5	N/C		

VOLTAGE TOLERANCE

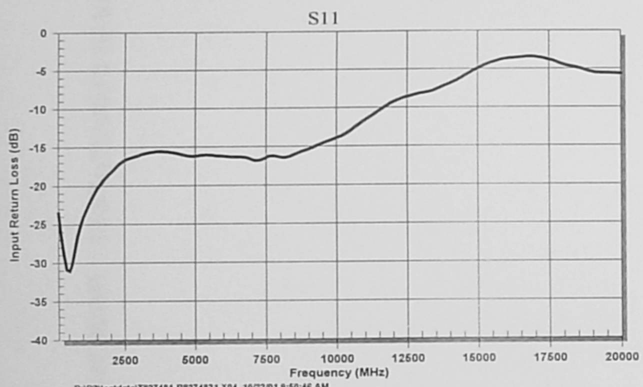
SUPPLY	PERMISSABLE RANGE
-12	-10 TO -15
+12	+10 TO +15
+4	+3 TO +6

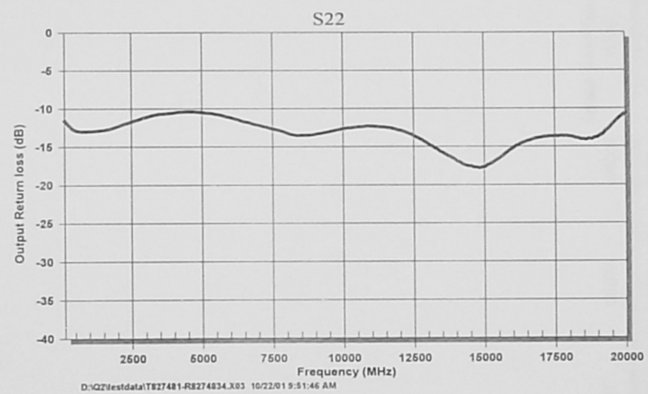




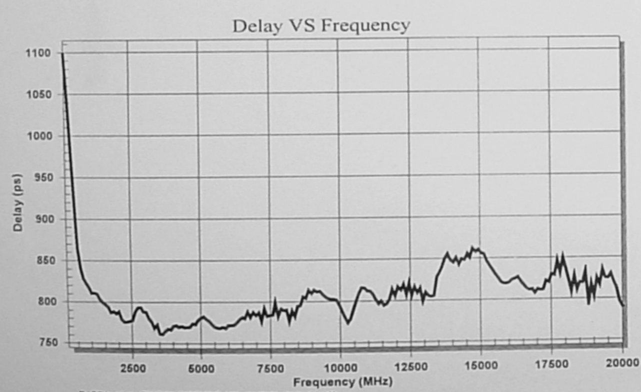
100 Davids Drive
Hauppauge NY 11788
Phone: (631) 439 - 9458

Model #: MDD-136821-P FIBER OPTIC LINK
Customer: DFAS-DY/FPB DAYTON OPER LOC
Customer PO:
Serial #:T827481-R827483
Project #:098441
Housing:
StockNo:
Voltage:+12/-12/+4/+12
Current:295/11/269/151
Temperature:20°C
Tested By:M SYED
Comment:





Freq (MHz)	Gain	Rev. Gain	In. VSWR	Out. VSWR	Group Delay
1000	19.78	-45.19	-24.38	-12.97	812
2000	19.08	-46.73	-18.26	-12.33	788
3000	18.52	-52.58	-16.04	-11.13	788
4000	17.76	-48.62	-15.61	-10.54	771
5000	18.00	-53.3	-16.20	-10.49	781
6000	17.96	-52.52	-16.23	-11.17	772
7000	18.62	-54.96	-16.69	-12.15	784
8000	19.27	-53.05	-16.39	-13.21	790
9000	19.71	-51.55	-15.38	-13.38	811
10000	19.35	-55.46	-13.92	-12.65	793
11000	19.41	-59.55	-11.63	-12.33	812
12000	19.32	-53.26	-9.29	-12.85	811
13000	18.91	-56.99	-8.15	-14.62	805
14000	18.71	-57.75	-6.92	-16.80	846
15000	17.09	-53.74	-4.94	-17.65	858
16000	13.42	-52.08	-3.69	-15.24	820
17000	10.19	-52.89	-3.47	-13.83	811
18000	06.40	-52.57	-4.47	-13.68	838
19000	02.59	-55.19	-5.43	-13.80	805
20000	-02.40	-49.4	-5.66	-10.64	790



Appendix 2: MathCad Calculations of Link Performance, based on Scott, Vang, et al [1]

$mW := 10^{-3} \cdot W$ $mA := 10^{-3} \cdot A$ $T := 290 \cdot K$ $k := 1.38 \cdot 10^{-23} \cdot J \cdot K^{-1}$ $e := 1.602 \cdot 10^{-19} \cdot C$ $Z_0 := 50 \cdot \Omega$ $c := 2.998 \cdot 10^{8} \cdot m \cdot s^{-1}$ $h := 6.626 \cdot 10^{-34} \cdot J \cdot s$ $\lambda := 1.55 \cdot 10^{-6} \cdot m$

dB to / from power ratio conversion $dB(x) := 10 \cdot \log(x)$ $INVdB(x) \equiv \sqrt[10]{10^{x}}$ $dBm(P) := dB\left(\frac{P}{1 \cdot mW}\right)$

Nominal Power $P_L := 10 \cdot mW$

Ideal Modulator V_π $V_\pi := 5 \cdot V$

Modulator Loss $L_M := INVdB(0)$

Fiber Loss $L_F := INVdB(0)$

$dBm\left(k \cdot T \cdot s^{-1}\right) = -173.977$ dBm/Hz

$INVdBm(x) := INVdB(x) \cdot 1mW$

Modulator Z $R_M := Z_0$

Detector Z $R_D := Z_0$

Responsivity $\eta_D := 0.7 \cdot A \cdot W^{-1}$

Laser RIN $RIN := INVdB(-160) \cdot Hz^{-1}$

Nominal PD Current $I_d := P_L \cdot L_M \cdot L_F \cdot \eta_D$ $I_d = 7\,mA$

Notes:
All IP3 values or calculations are referred to input

Externally Modulated Link Gain, NF, Dynamic Range Without Amplifiers

$g(P_L, V_\pi) := \left(\frac{\pi \cdot P_L}{2 \cdot V_\pi}\right)^2 \cdot \left(\eta_D \cdot L_M \cdot L_F\right)^2 \cdot R_M \cdot R_D$ $G(P_L, V_\pi) := dB\left(g(P_L, V_\pi)\right)$ $G(P_L, V_\pi) = -19.176$ dB $g(P_L, V_\pi) = 0.012$

$dBm_{IP3}(V_\pi) := dBm\left[\frac{4}{R_M} \cdot \left(\frac{V_\pi}{\pi}\right)^2\right]$ $IIP3_{phot} := \frac{4}{R_D}\left(\frac{V_\pi}{\pi}\right)^2$ $dBm\left(IIP3_{phot}\right) = 23.067$ IP3 of Photonic Portion of Link

$OIP3_{phot} := IIP3_{phot} \cdot g(P_L, V_\pi)$ $dBm\left(OIP3_{phot}\right) = 3.892$ dBm $OIP3_{phot} = 2.45 \times 10^{-3}\,W$

$N_{Thermal}(P_L, V_\pi) := k \cdot T \cdot s^{-1} \cdot \left(1 + g(P_L, V_\pi)\right)$ Thermal Noise from input and link

$N_{Shot}(P_L) := e \cdot \left(P_L \cdot L_M \cdot L_F \cdot \eta_D\right) \cdot R_D \cdot s^{-1}$ Shot noise $N_{Thermal}(P_L, V_\pi) = 0\,W$ $dBm\left(N_{Thermal}(P_L, V_\pi)\right) = -173.925$

$N_{RIN}(P_L) := RIN \cdot \left(P_L \cdot L_M \cdot L_F \cdot \eta_D\right)^2 \cdot R_D \cdot s^{-1}$ Relative Intensity Noise

$N_{Out} := \left(N_{Thermal}(P_L, V_\pi)\right) + \left(N_{Shot}(P_L)\right) + \left(N_{RIN}(P_L)\right)$ $N_{Out} = 0\,W$ $dBm\left(N_{Out}\right) = -155.155$

$NF_{phot} := \frac{N_{Out}}{k \cdot T \cdot g(P_L, V_\pi) \cdot s^{-1}}$ $dB\left(NF_{phot}\right) = 37.998$ dB NF for Photonic Portion of Link Total Link Noise Output

$SFDR_{phot} := \frac{2}{3} \cdot \left(dBm\left(OIP3_{phot}\right) - dBm\left(N_{Out}\right)\right)$ $SFDR_{phot} = 106.031$ dB/Hz^2/3 **A.2.1**

Adding LNA Preamplifier & Transimpedance Post-Amplifier:

$NF_{LNA} := 1.9$ $OIP3_{LNA} := INVdBm(25)$ $OIP3_{LNA} = 316.228\ mW$ $G_{LNA} := 36$ $INVdB(G_{LNA}) = 3.981 \times 10^{3}$ $IIP3_{LNA} := \frac{OIP3_{LNA}}{G_{LNA}}$

$NF_{postamp} := 3$ dB $OIP3_{postamp} := 0$ dBm $G_{postamp} := -.67$ dB

$$NF_{overall} := dB\left(INVdB(NF_{LNA}) + \frac{NF_{phot} - 1}{INVdB(G_{LNA})} + \frac{INVdB(NF_{postamp}) - 1}{INVdB(G_{LNA}) \cdot INVdB(G_{postamp})}\right)$$ $NF_{overall} = 4.959$ dB

$$OIP3_{overall} := \left(\left(\frac{1}{g(P_L, V_\pi) \cdot OIP3_{LNA} \cdot INVdB(G_{postamp})} + \frac{1}{IIP3_{phot} \cdot g(P_L, V_\pi) \cdot INVdB(G_{postamp})} + \frac{1}{INVdBm(OIP3_{postamp})}\right)\right)^{-1}$$

$dBm(OIP3_{overall}) = -2.508$ dBm

$$SFDR_{overall} := \frac{2}{3} \cdot \left(dBm(OIP3_{overall}) - dBm(k \cdot T \cdot s^{-1}) + NF_{overall}\right)$$ $SFDR_{overall} = 117.619$

$G_{overall} := G(P_L, V_\pi) + G_{LNA} + G_{postamp}$ $G_{overall} = 16.154$

Conclusion: Overall Predicted Performance
RF Gain=16.15 dB, NF=4.96 dB
OIP_3=-2.51 dBm, MDS=-170.0 dBm,
SFDR=117.62 dB/Hz^2/3

A.2.2

Appendix 3: Other Tested Links

In order to compare the performance of the RF link to be used in the modular test-bed, we evaluated two different RF links, a 2-18 GHz externally-modulated RF link described in the AFRL Technical Report Number AFRL-SN-RS-TR-1998-195 [5], and a commercially available RF link from MITEQ Corporation, Model Number MDD-136821-P.

The first link we tested was a 2-18 GHz externally-modulated link developed under contract by Uniphase Telecommunications Products, and described in the aforementioned Final Technical Report. We used the link with serial number 002 for our tests. We tested the gain, noise figure and IP_3 of this link and compared the results with those called out in the Technical Report. As can be seen in figures A.3.1 to A.3.4, the current measured performance of the link has degraded since 1998; the recently measured values are those connected by a line. The noise figure of the link is almost double that of the original values; the gain has decreased by about roughly 15 dB; the IP_3 has decreased by about 4 dB; and the dynamic range has decreased by over 5 dB. Clearly, this link does not attain the same level of performance as the link we have set up, and is even further from satisfying the performance requirements for insertion into the radar set. We were able to improve the performance of the system by replacing the optical connectors with today's standard FC/PC connectors, as can be seen in figure A.3.1.

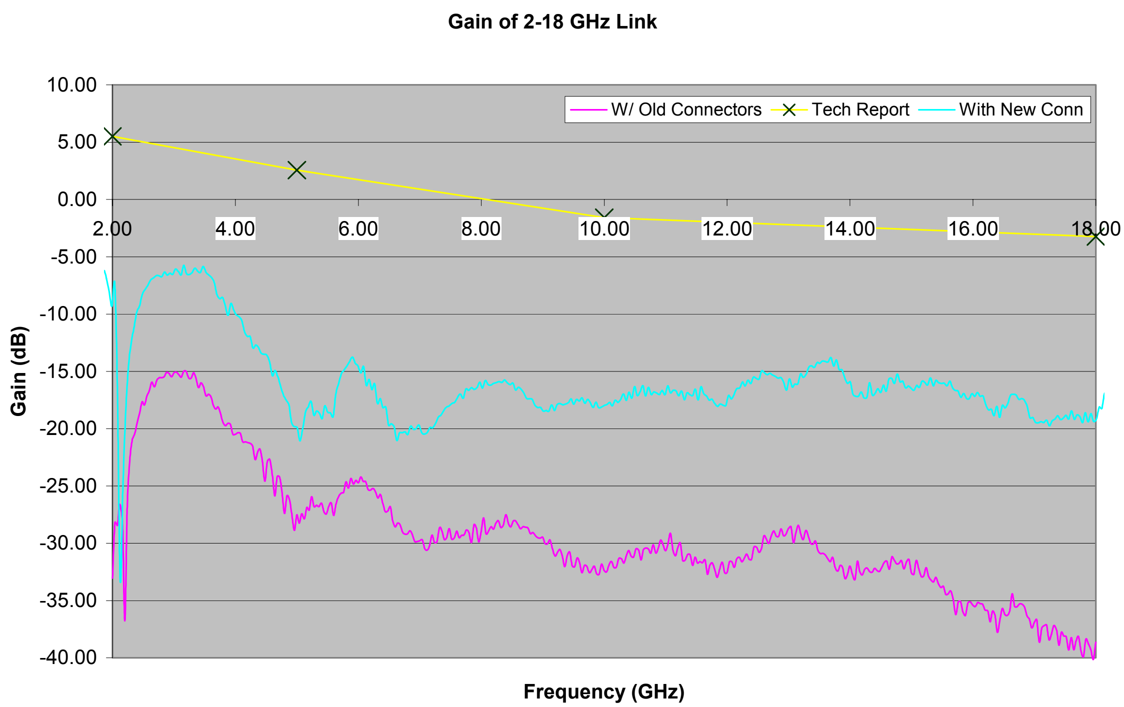


Figure A.3.1: Gain of the 2-18 GHZ UTP Developmental Link Using an HP 86030A Network Analyzer

A.3.1

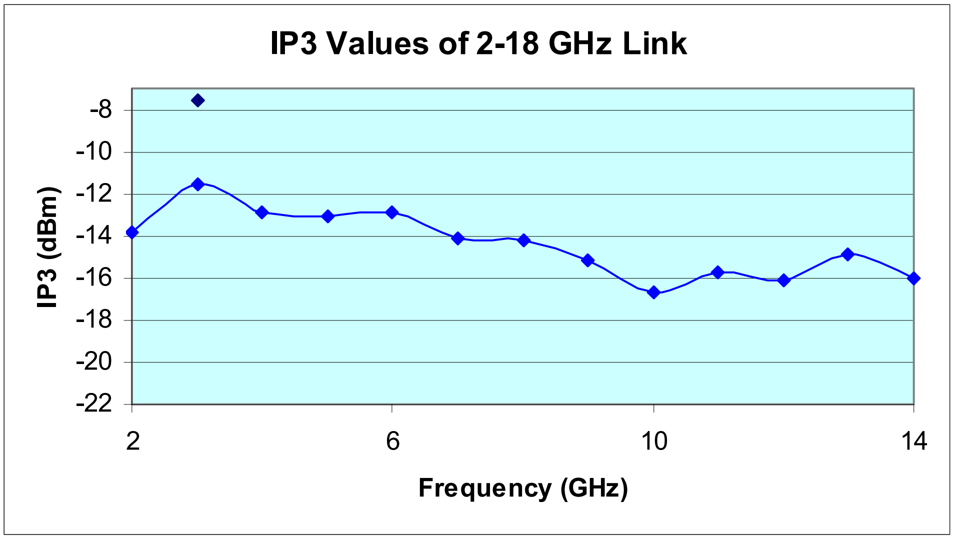


Figure A.3.2: IP_3 Values for the 2-18 GHz Link Using HP 8593E Signal Analyzer

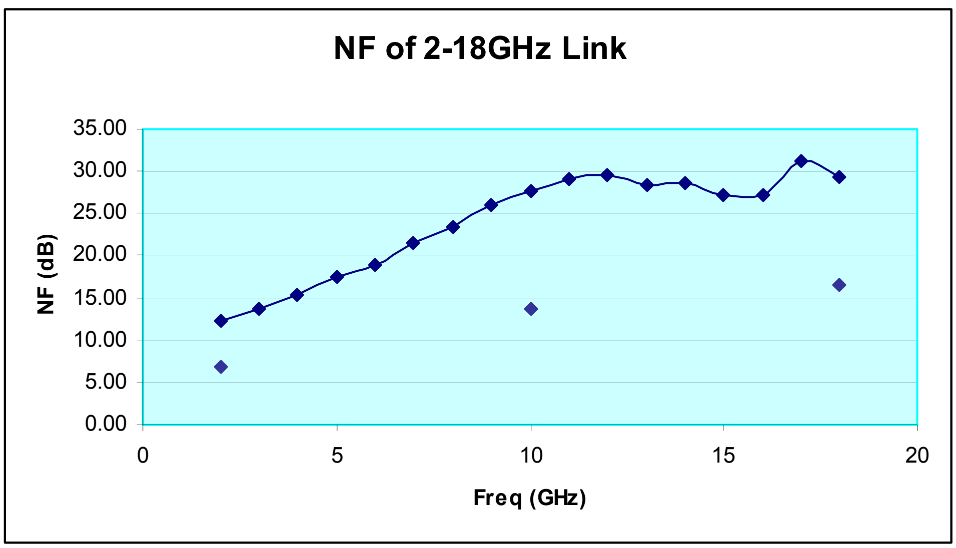


Figure A.3.3: Noise Figure for the 2-18 GHz Link using a 71400C Signal Analyzer with a Noise Figure Measurement Personality Loaded

A.3.2

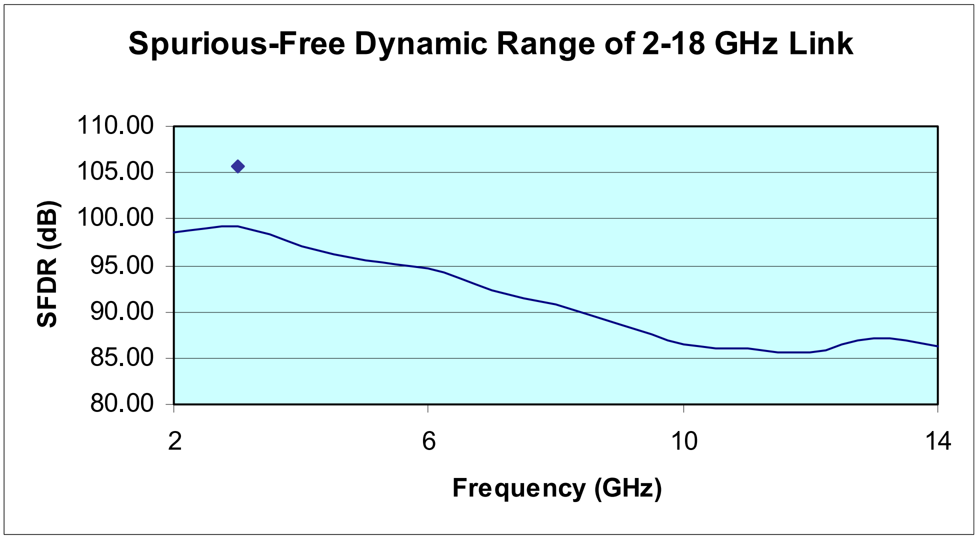


Figure A.3.4: SFDR for the 2-18 GHz Link

The second RF link we had available to us for testing was a MITEQ model # MDD-136821-P directly-modulated link. This link has a rated bandwidth of about 18 GHz and a rated gain and noise figure of 18 dB and 15 dB, respectively. We only tested this link at one frequency, 1 GHz. The IP_3 of the link was 2.48 dBm at this frequency, which was obviously much better than any of the externally-modulated cases. However, using this value and the specified noise figure of 12 dB, the dynamic range is 98.67 dB/$HZ^{2/3}$, which is still too low for our application.

Below are the noise figure and gain plots for the MITEQ link, as well as a plot of the magnitude of the microwave gain versus frequency, $|S_{21}|$, of the same link over the frequency range of 100 kHz to 20 GHz. Note that the measured values below match closely with those in the datasheet for the link in Appendix 1.

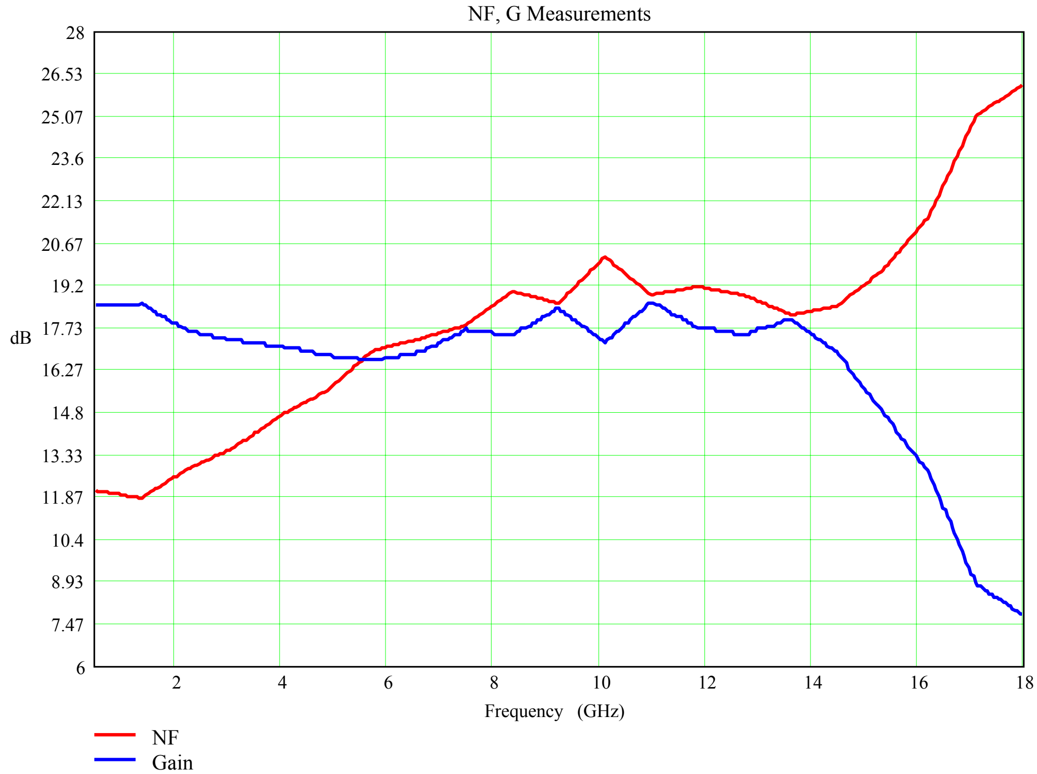


Figure A.3.5: MITEQ Link NF & Gain

A.3.4

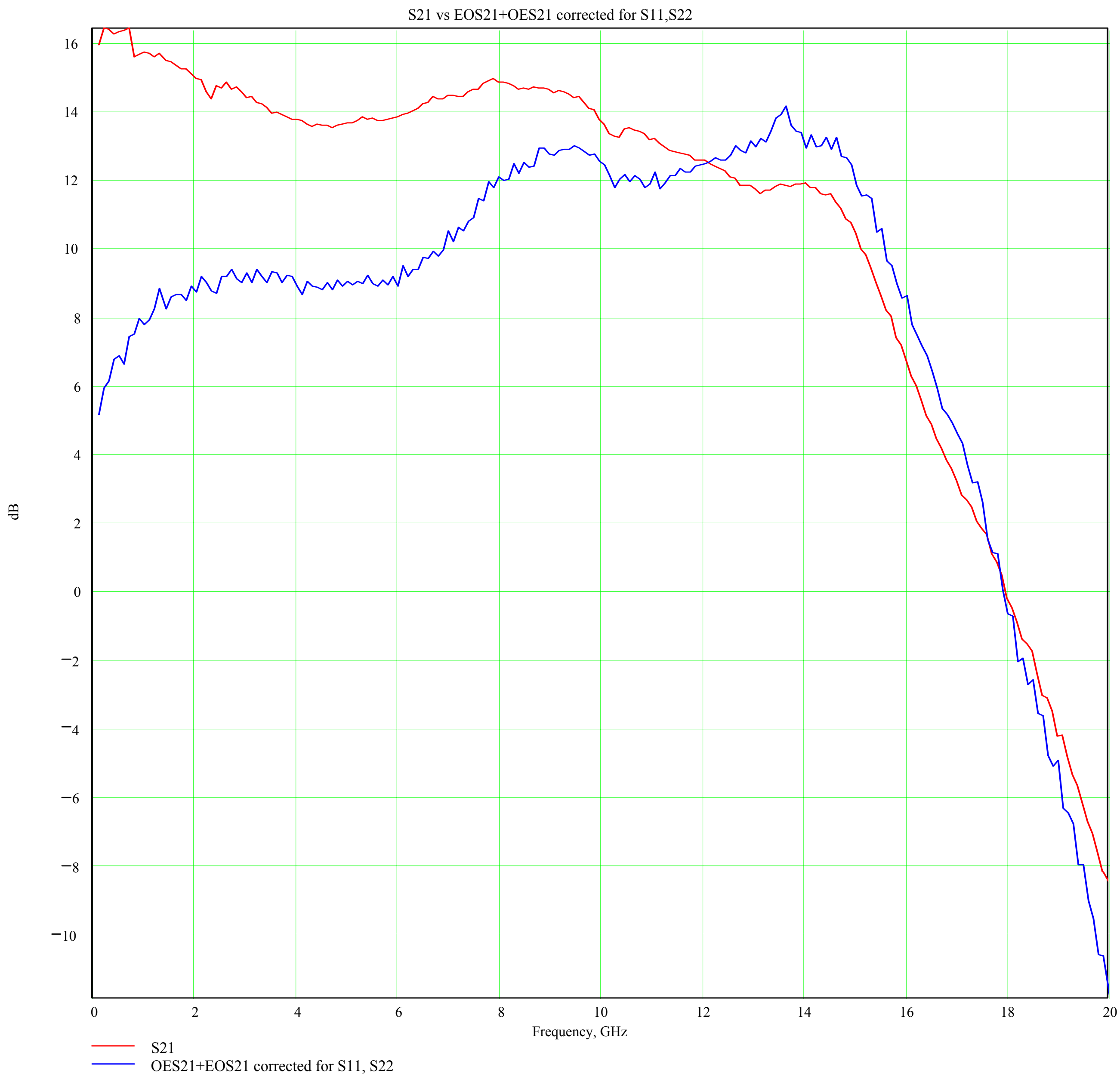


Figure A.3.6: Overall MITEQ Link $|S_{21}|$

A.3.5

References

[1] D.C. Scott, T.A. Vang, J. Elliott, D. Forbes, J. Lacey, K. Everett, F. Alvarez, R. Johnson, A. Krispin, J. Brock, L. Lembo, H. Jiang, D. Shin, J. Zhu, P. K. L. Yu, "Measurement of IP_3 in p-i-n Photodetectors and Proposed Performance Requirements for RF Fiber-Optic Links," *IEEE Photonics Technology Letters,* Vol 12, No 4, April 2000, pp 422-424

[2] ILX Lightwave Customer Support Website: http://www.ilxlightwave.com → go to sections on LDX-3100 (LD Current Source) and LDT-5100 (LD Temp Controller)

[3] Reinhold Ludwig & Pavel Bretchko, *RF Circuit Design: Theory and Applications*, Prentice Hall Press, NJ, 2000, pp524-525

[4] C.H. Cox III & E.I. Ackerman, "Some Limits on the Performance of an Analog Optical Link," *SPIE Proceedings,* Vol 3463, July 1998, pp 2-7

[5] Ronald Logan, Jr., *High Fidelity Microwave Remoting, Air Force Research Laboratory Final Technical Report AFRL-SN-RS-TR-1998-195,* Air Force Research Laboratory, Rome, NY, October 1998

[5] T. Vang, E. Twyford-Kunkee, D.C. Scot, D. Forbes, R. Davis, J. Elliott, J.C. Brock, L. J. Lembo, "Semiconductor Optical Modulators for High-Performance Analog RF Photonic Links and Signal Processing," SPIE Proceedings, Vol 3950, 2000, pp 238-245