Reference Design:

HFRD-02.0
Rev 1; 10/05

REFERENCE DESIGN

HFRD-2.0: 2.5Gbps Small Form Factor (SFF) Transmitter

MAXIM High-Frequency/Fiber Communications Group

Maxim Integrated Products

Reference Design: 2.5Gbps Small Form Factor (SFF) Transmitter

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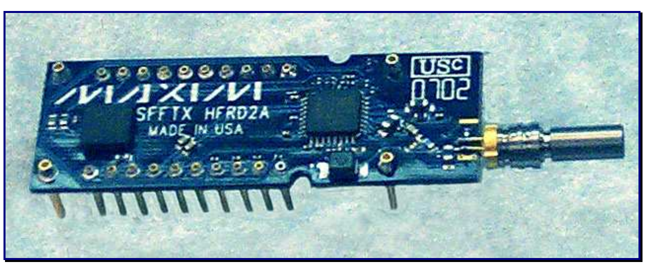
1 Overview

High Frequency Reference Design (HFRD) 2.0 is a complete transmitter that is compliant with the Small Form Factor (SFF) Multisource Agreement (MSA). Data rates up to 2.5Gbps are attainable with the high-speed Fabry-Perot laser and the MAX3863 high-speed direct modulation laser driver. Average power and extinction ratio are held constant over the full –40°C to +85°C temperature range using the Dallas Semiconductor DS1847 dual temperature-controlled digital resistor, that can be programmed using an industry standard 2-wire interface.



The HFRD-2.0 transmitter reduces design time for SFF and other optical transmitters by providing the schematics, PC board layout, Gerber files and bill of materials for a complete SFF transmitter. Test data and typical performance from an assembled board are also given, to aid in the evaluation of this reference design. The receiver section of the SFF board can be implemented using the extra space on the underside of the PC board. The HFRD-2.0 includes a SFF transmitter board (2.0A) and a host board (2.0B).

1.1 Features

- Schematics and Bill of Materials Provided
- Gerber Plot Files Available
- PC Board Includes Space for Receiver
- Up to 2.5 Gbps Optical Transmission
- Single +3.3V Power Supply
- 2x10 Pin SFF Multisource Footprint
- Transmitter Power Monitors
- 1300nm Wavelength FP Laser
- -40°C to +85°C Operating Range
- Temperature Compensation using Variable Digital Resistors with Look-Up Table
- Compatible with LC Fiber-Optic Connector
- Assembled SFF Transmitter Board (HFRD-2.0A) and SFF Host Board (HFRD-2.0B) Available for Evaluation

2 Obtaining Additional Information

Limited quantities of the HFRD-2.0A SFF transmitter board and HFRD-2.0B host board are available. For more information about the reference design or to obtain an SFF transmitter and/or host board please call (503) 547-2400 between 8 a.m. and 5 p.m. Pacific time.

3 Reference Design Details

The HFRD-2.0 SFF transmitter reference design (Figure 1) is implemented using a high-speed laser driver (MAX3863), a dual temperature-controlled variable resistor (DS1847) and a Fabry-Perot laser (SLT2170-LN). The design is SFF MSA compliant and incorporates the optional current monitoring features. Board space and extra considerations were used in the design to allow implementation of the receiver section on the underside of the PCB.

3.1 MAX3863 Laser Driver

The MAX3863 is designed for direct modulation of laser diodes at data rates up to 2.7Gbps. An automatic power control (APC) loop and modulation compensation are used to maintain average power and extinction ratio over temperature.

The MAX3863 can modulate laser diodes at amplitudes up to 80mAp-p and supply bias currents up to 100mA. Typical edge speeds are 50ps.

The MAX3863 includes adjustable pulse-width control to minimize laser pulse-width distortion. In addition, the MAX3863 features duty-cycle and current monitors. A failure monitor output is provided to indicate when the APC loop is unable to maintain the average optical power.

For additional information see the MAX3863 data sheet available on the web at www.maxim-ic.com.

3.2 DS1847 Digital Potentiometer

The DS1847 Dual Temperature-Controlled NV Variable Resistor consists of one 50kΩ 256-position variable resistor, one 10kΩ 256-position variable resistor, and a "Direct-to-Digital" temperature sensor. The device provides temperature-compensation to the bias and modulation currents by changing the total resistance seen by the current-setting pins of the MAX3863.

The variable resistors' settings are stored in EEPROM memory and can be accessed over the industry standard 2-wire serial bus. The value of each variable resistor is determined by a temperature-addressed look-up table, which can assign a unique value to each resistor for every 2°C increment over the –40°C to +85°C range. The interface I/O pins consist of SDA and SCL.

For additional information see the DS1847 data sheet available on the web at www.maxim-ic.com.

3.3 ExceLight Laser

The SLT2170-LN, manufactured by ExceLight, is a 1.3µm InGaAsP/InP MQW-FP laser diode, suited for LC-connector fiber-optic transmitters up to 2.5Gbps.

For additional information see the SLT2170-xN series data sheet available on the web at www.excelight.com.

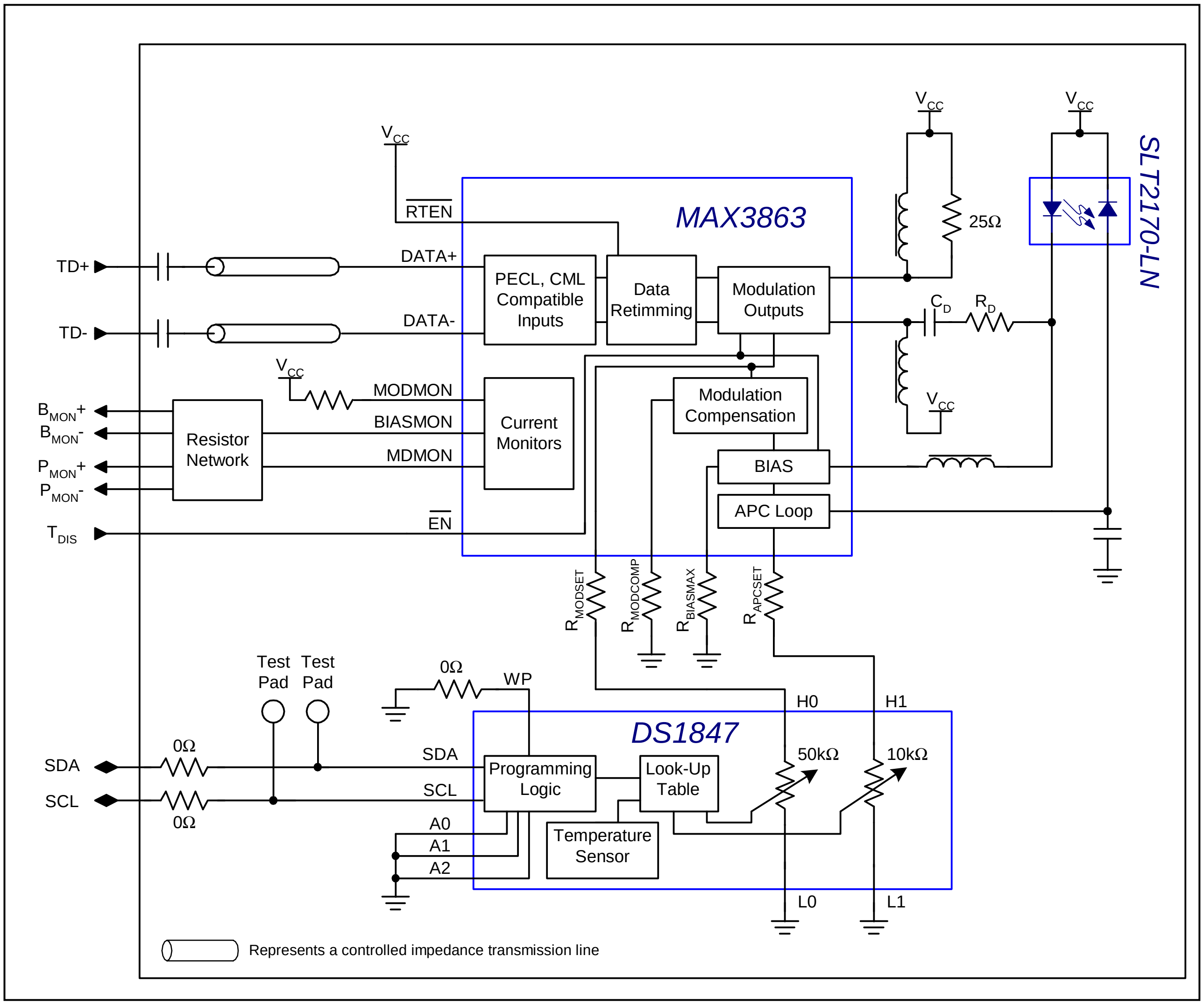


Figure 1: Functional Diagram

4 Recommended Operating Conditions

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Operating Ambient Temperature	T_A		-40		85	^oC
Supply Voltage	V_{CC}		3.1	3.3	3.6	V
Input Data Rate			.622	2.5	2.7	Gbps
Differential Input Voltage			200		1600	mV_{p-p}
TTL Input Voltage (Low)					0.8	V
TTL Input Voltage (High)			2			V

5 Typical Reference Design Performance

(Typical values are measured at T_A = +25^{o}C, V_{CC} = +3.3V, Average Power = -4.5dBm, Extinction Ratio = 9.2dB unless otherwise noted.)

PARAMETER	SYMBOL	CONDITIONS	TYP	UNITS
Power Supply Current			116	mA
Average Power			-4.5	dBm
Extinction Ratio	E_R		9.2	dB
Extinction Ratio Variation		-40^{o}C to +85^{o}C	.4	dB
Optical Rise Time	t_R	20% to 80% (note 1)	38	ps
Optical Fall Time	t_F	80% to 20% (note 1)	146	ps
Jitter Generation	TJ	Total Jitter Peak to Peak (note 2)	100	mUI
	RJ	RMS Random Jitter (note 1)	3.4	mUI
Eye Mask Margin		25^{o}C (note 2)	15	%
Center Wavelength			1310	nm
Bias Current Monitor Voltage	V_{BMON}	Max = I_{BIAS} (MAX) * 10Ω	670	mV
		Min = I_{BIAS} (MIN) * 10Ω	53	mV
Optical Power Monitor Voltage (Monitor Photodiode)	V_{PMON}	Max = I_{MD} (MAX) * 205Ω	170	mV
		Min = I_{MD} (MIN) * 205Ω	30	mV
T_{DIS} Assert Time	t_off	Time from rising edge of T_{DIS} to optical power at 5% of steady state.	146	ns
T_{DIS} Deassert Time	t_on	Time from falling edge of T_{DIS} to optical power at 95% of steady state.	160	ns
Initialization Time	t_init	Time from power ON to optical power at 95% of steady state.	4.5	ms

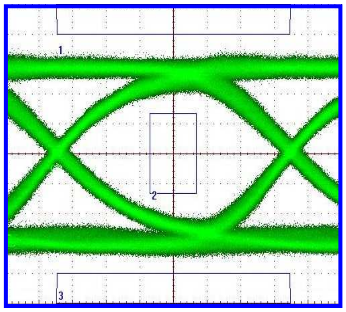
Note 1: Measured using a 2.488Gbps repeating 0000 1111 pattern.

Note 2: Measured using a 2.488Gbps with a 2^{23}-1 PRBS input data pattern.

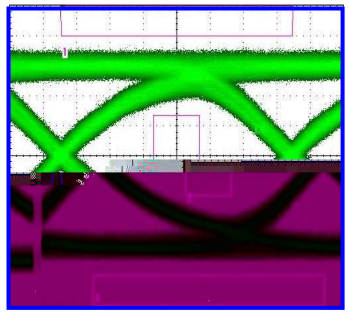
6 Reference Design Characteristic Graphs

(T_A = +25°C, V_{CC} = +3.3V, 2^{23}-1 PRBS at 2.4883Gbps, unless otherwise noted)

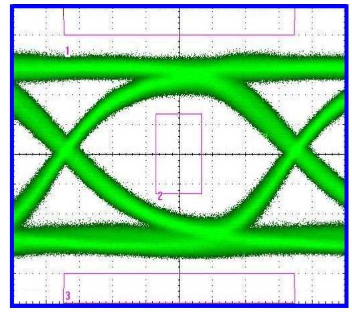
OPTICAL EYE DIAGRAM
(E_R = 9.31dB, 2.488Gbps, 1.87GHz Filter)



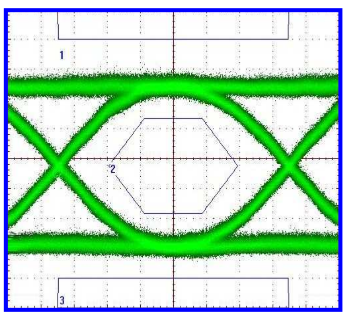
OPTICAL EYE DIAGRAM
(E_R = 9.09dB, 2.488Gbps, 1.87GHz Filter, T_A = -40°C)



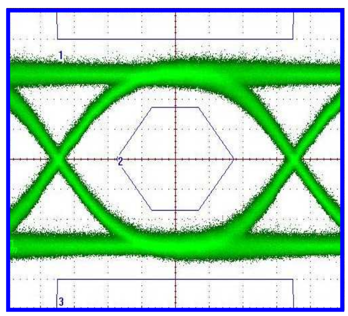
OPTICAL EYE DIAGRAM
(E_R = 9.14dB, 2.488Gbps, 1.87GHz Filter, T_A = +85°C)



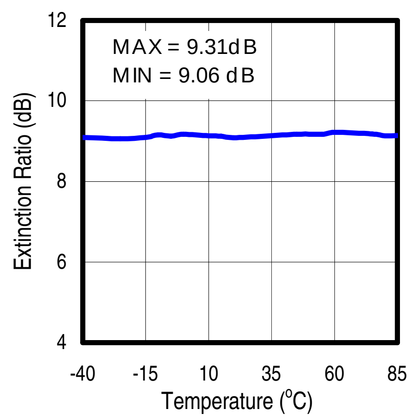
OPTICAL EYE DIAGRAM
(E_R = 11.5dB, 1.25Gbps, 933MHz Filter)



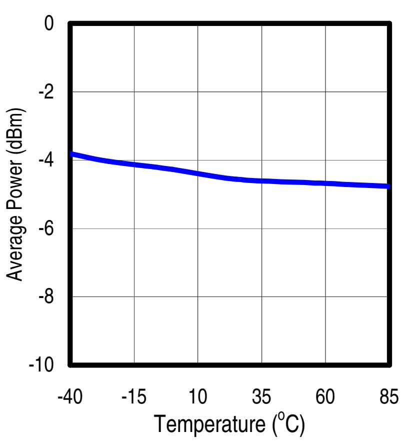
OPTICAL EYE DIAGRAM
(E_R = 11.5dB, 622Mbps, 467MHz Filter)



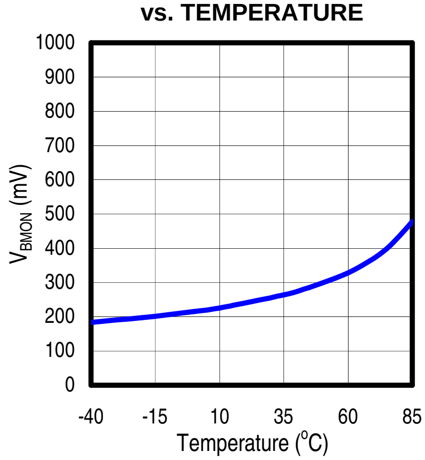
EXTINCTION RATIO vs. TEMPERATURE



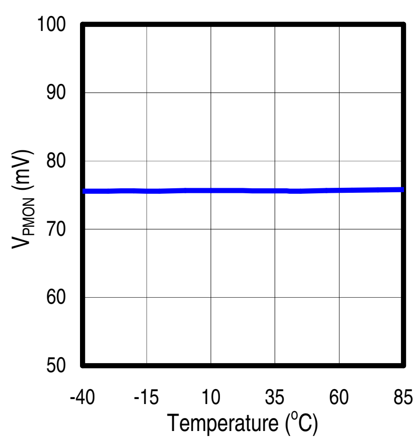
AVERAGE OPTICAL POWER vs. TEMPERATURE



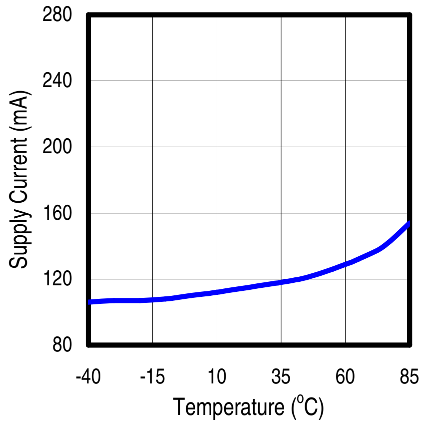
BIAS CURRENT MONITOR VOLTAGE vs. TEMPERATURE



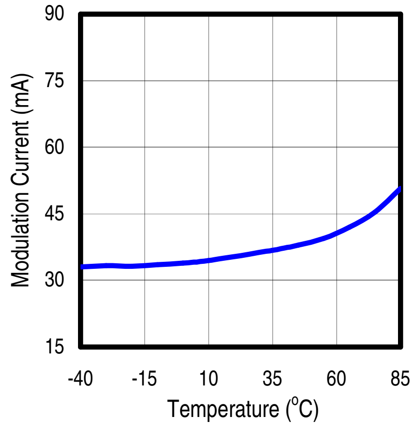
PHOTODIODE MONITOR VOLTAGE vs. TEMPERATURE



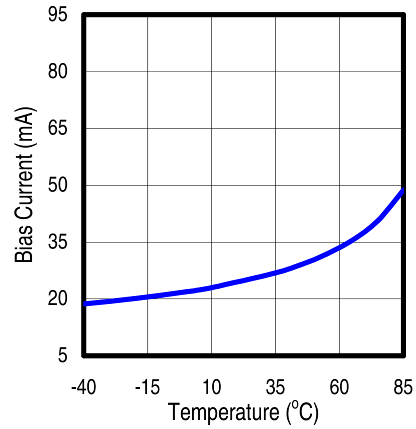
SUPPLY CURRENT vs. TEMPERATURE



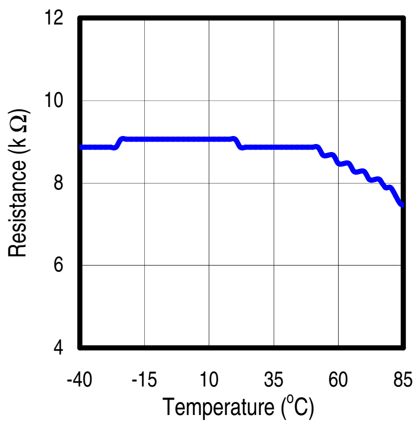
MODULATION CURRENT vs. TEMPERATURE



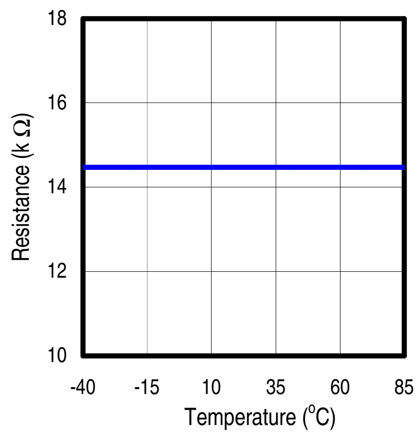
BIAS CURRENT vs. TEMPERATURE



R_{MODSET} vs. TEMPERATURE



R_{APCSET} vs. TEMPERATURE



Temperature	Digital Change in Rmodset	Temperature	Digital Change in Rmodset	Temperature	Digital Change in Rmodset
-40	-1	4	0	48	-1
-38	-1	6	0	50	-1
-36	-1	8	0	52	-1
-34	-1	10	0	54	-2
-32	-1	12	0	56	-2
-30	-1	14	0	58	-2
-28	-1	16	0	60	-3
-26	-1	18	0	62	-3
-24	0	20	0	64	-3
-22	0	22	-1	66	-4
-20	0	24	-1	68	-4
-18	0	26	-1	70	-4
-16	0	28	-1	72	-5
-14	0	30	-1	74	-5
-12	0	32	-1	76	-5
-10	0	34	-1	78	-6
-8	0	36	-1	80	-6
-6	0	38	-1	82	-7
-4	0	40	-1	84	-8
-2	0	42	-1	86	-8
0	0	44	-1	88	-9
2	0	46	-1	90	-9

7 Application Information

7.1 Small Form Factor Modules

The HFRD-2.0A SFF transmitter design was specifically engineered to meet the requirements of the Small Form Factor (SFF) Transceiver Multisource Agreement (MSA). The SFF MSA sets guidelines for the package outline, pin function, and other aspects of the module design. By complying with the standard, modules are mechanically and functionally interchangeable.

7.2 Monitor Outputs

The MAX3863 has on-chip current monitors for bias, modulation and monitor diode current. The resistor network, shown in Figure 2, is used to comply with the specifications for the monitors as detailed in the SFF MSA.

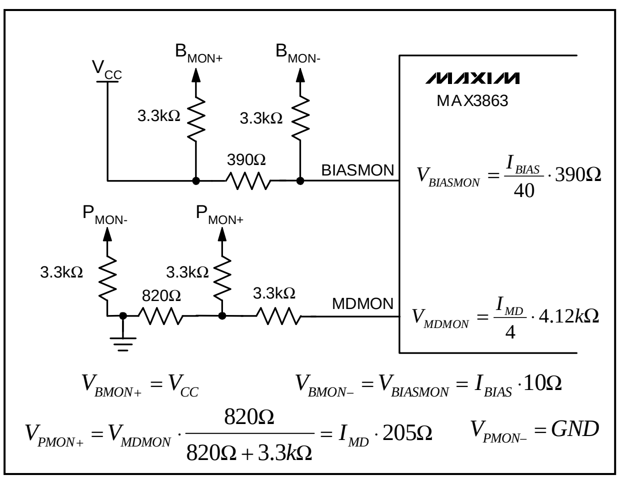


Figure 2: Resistor Network

The voltage across pins 17 and 18 of the SFF module is equivalent to the bias current through a 10Ω resistance between the two pins. The voltage across pins 19 and 20 is equivalent to the monitor diode current through a 205Ω resistance. Refer to *Typical Operating Characteristics* "V_{BMON} vs. Bias Current" and "V_{PMON} vs. Monitor Diode Current" graphs for typical values. The relations are given mathematically as:

$$I_{BIAS} = \frac{(B_{MON+} - B_{MON-})V}{10\Omega}$$

$$I_{MD} = \frac{(P_{MON+} - P_{MON-})V}{205\Omega}$$

7.3 Programming the DS1847

The DS1847 dual variable resistor is programmed with an industry standard 2-wire interface. The interface I/O pins consist of SDA and SCL (see the DS1847 data sheet for more information). To facilitate the evaluation of the SFF transmitter, these control lines are connected (through zero ohm resistors) to pin 9 and pin 10 of the module (RD+ and RD-). The data can then be programmed into the device through these pins using the connections of a standard SFF evaluation kit. In production, the zero-ohm resistors and connections to these pins should be removed. The DS1847 would then be programmed using the test pads as connection points to the I/O lines during the manufacturing process.

To facilitate the programming of the DS1847, additional materials such as software, serial port dongle, cable and HFRD-2.0B host board can be used. These materials allow easy adjustments to be made to the DS1847 through a 2-wire interface. See *Additional Evaluation Materials* on page 16 for more information.

7.4 Receiver Design

The reference design does not include a receiver. The PC board was intentionally designed to leave space for a receiver on the underside of the board.

7.5 Layout Considerations

Differential and single-ended transmission lines are included in this reference design. Changing the PCB layer profile (see details on page 16) can affect the impedance of these transmission lines and hence the performance of the module. If the layer profile is changed, the transmission line dimensions should be recalculated.

7.6 Host Board Requirements

Controlled impedance transmission lines and good high-frequency design techniques should be used when interfacing to the HFRD-2.0A. The host board should also provide the necessary power-supply filtering. A recommended power supply filter is shown in Figure 3.

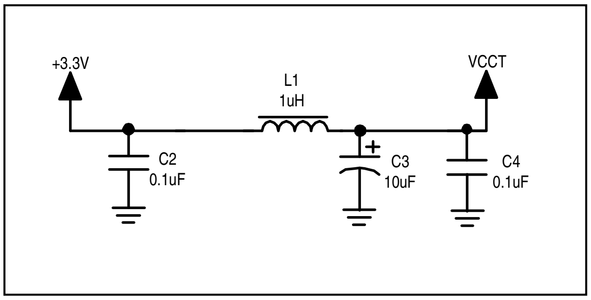


Figure 3: Power Supply Filter

7.7 SFF Compliance, EMI and Safety Issues

Full compliance to the SFF MSA and other performance specifications cannot be guaranteed by Maxim and are therefore the responsibility of the user of this reference design. This reference design is intended to aid SFF module designers and is not intended to take the place of the entire design process. The SFF module designer should evaluate the reference design and modify it as necessary to meet the specification for each particular project. The designer should also carefully consider safety and EMI issues related to the particular application.

8 Quick Start

The HFRD-2.0A can be evaluated in a standard SFF host board, Do not make connections to pins 9 and 10 as the DC voltages on these pins created by the 2-wire interface could damage equipment. If changes to the settings of the DS1847 are not needed or not performed, remove zero-ohm jumpers R16 and R17 (see Section 12 schematics) to open the SDA and SCL connections to pins 9 and 10 of the SFF module. The module has been pre-programmed prior to shipment to provide an extinction ratio of 9dB and an average power of -4.5dBm at 25°C. The temperature-controlled look-up table has also been programmed to maintain extinction ratio over temperature.

Precautions must be taken in order to insure safe operation when using a device with a laser diode. Laser-light emissions can be harmful and may cause eye damage. Maxim assumes no responsibility for harm or injury as a result of the use of this reference design. The safe operation of this design is the sole responsibility of the user.

To evaluate the HFRD-2.0A in a standard SFF host board:

1) Connect the HFRD-2.0A to an SFF host board.
2) Attach a 2.5Gbps differential source to the host board so that data is applied to pins 14 and 15 of the SFF module. Each source should have a peak-to-peak amplitude between 100mV and 800mV (200mV and 1600mV differential).
3) Connect a single-mode fiber with an LC-type ferrule to the laser. Do not place mechanical stress on the laser with the fiber cable. Stress by the fiber cable or other sources could damage the laser.
4) Connect the other end of the fiber to a high-speed oscilloscope through an optical-to-electrical converter or an optical plug-in module. The optical-to-electrical conversion device should have a bandwidth of at least 1870MHz and be able to detect 1310nm wavelengths. **Note: The laser supplied with the reference design has a maximum power rating of 0.8mW. Attenuation may be required if 0.8mW of optical power exceeds the optical-to-electrical device's input power rating.**
5) Apply a +3.3V power supply to the host board. Set the current limit to 200mA.
6) Verify that T_{DIS} is deasserted, so that the SFF module may operate.

9 Pin Description

PIN	NAME	FUNCTION
MS	MS	Mounting Studs, Tie to Chassis Ground
1-8		No Connection
9	SDA	2-Wire interface for evaluation only – See *Applications Information*
10	SCL	2-Wire interface for evaluation only – See *Applications Information*
11	$V_{CC}T$	+3.3V, Positive Transmitter Power Supply
12	$V_{EE}T$	Transmitter Signal Ground
13	T_{DIS}	Transmitter Disable, TTL – High to disable, low to enable
14	TD+	Non-Inverted Transmitter Data Input, PECL Compatible
15	TD-	Inverted Transmitter Data Input, PECL Compatible
16	$V_{EE}T$	Transmitter Signal Ground
17	B_{MON-}	Laser Diode Bias Current Monitor – Negative End
18	B_{MON+}	Laser Diode Bias Current Monitor – Positive End
19	P_{MON-}	Laser Diode Optical Power Monitor – Negative End
20	P_{MON+}	Laser Diode Optical Power Monitor – Positive End

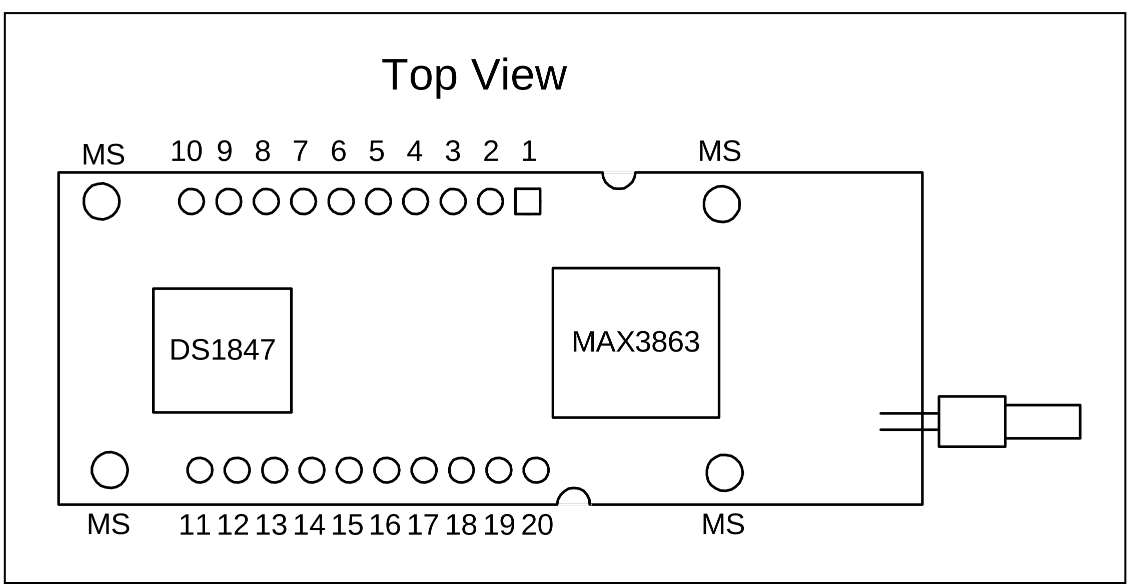


Figure 4. 2.0A SFF Board Pin Diagram (Top View)

10 Component List (SFF Board)

DESIGNATION	QTY	DESCRIPTION
C1, C4-8, C10-15, C32	12	0.01uF ± 10% Ceramic Capacitor (0201)
C2, C3, C27	2	0.1uF ± 10% Ceramic Capacitor (0402)
C9, C28	2	Open (0201)
C30	1	470pF ± 10% Ceramic Capacitor (0201)
D1	1	FP Laser Diode ExceLight SLT2170-LN
L1, L10-11	3	Ferrite Beads (0603) Murata BLM18HG601SN1
L7	1	33uH Inductor Toko FSLB2520-330K
MP1-MP4	4	Mounting Pins, Mill Max 3102-2-00-21-0000080 Digi-Key ED5050-ND
P1-P20	20	Connection Pins, Mill Max 3117-1-00-21-0000080 Digi-Key ED5055-ND
R4-6, R8, R11, R14	6	3.3kΩ ±5% Resistor (0201)
R7	1	20kΩ ±1% Resistor (0201)
R9, R10	2	2.2kΩ ±5% Resistor (0201)
R12	1	100Ω ±5% Resistor (0201)
R13	1	390Ω ±5% Resistor (0201)
R15	1	820Ω ±5% Resistor (0201)
R16, R17, R19	3	0Ω ±5% Resistor (0402)
R18	1	10kΩ ±5% Resistor (0201)
R20, R23	1	82Ω ±5% Resistor (0201)
R21, R24	2	470Ω ±5% Resistor (0201)
R22	1	Open (0201)
R25	1	24.9Ω ±1% Resistor (0402)
R51	1	18.0Ω ±1% Resistor (0402)
U1	1	MAX3863EGJ 32 Pin QFN (Exposed Pad)
U3	1	DS1847B-050 16 Ball BGA
None	1	SFF Module Board

11 Component List (Host Board)

DESIGNATION	QTY	DESCRIPTION
C1, C3	2	10uF ±10% Ceramic Capacitor AVX TAJC106K010R
C2	1	0.1uF ± 10% Ceramic Capacitor (0805)
C4	1	0.1uF ± 10% Ceramic Capacitor (0402)
J3, J4	2	SMA Edge-Mount Connectors
J2	1	6 Pin, Phone Jack Connector AMP 555077-1
JU1	1	1x3 Pin Headers (0.1in centers)
D1, D2	2	Red LED
L13	1	1uH Inductor
MS1-MS4	4	Mounting Sockets, Mill Max 0327-0-15-01-3427100 Digi-Key ED5016-ND
S1-S20	20	Connection Sockets, Mill Max 0680-0-15-01-3227100
R1, R2	1	330Ω ±5% Resistor (0603)
R3	1	49.9Ω ±1% Resistor (0402)
R4, R5	2	4.7kΩ ±5% Resistor (0603)

12 Schematics (SFF Board)

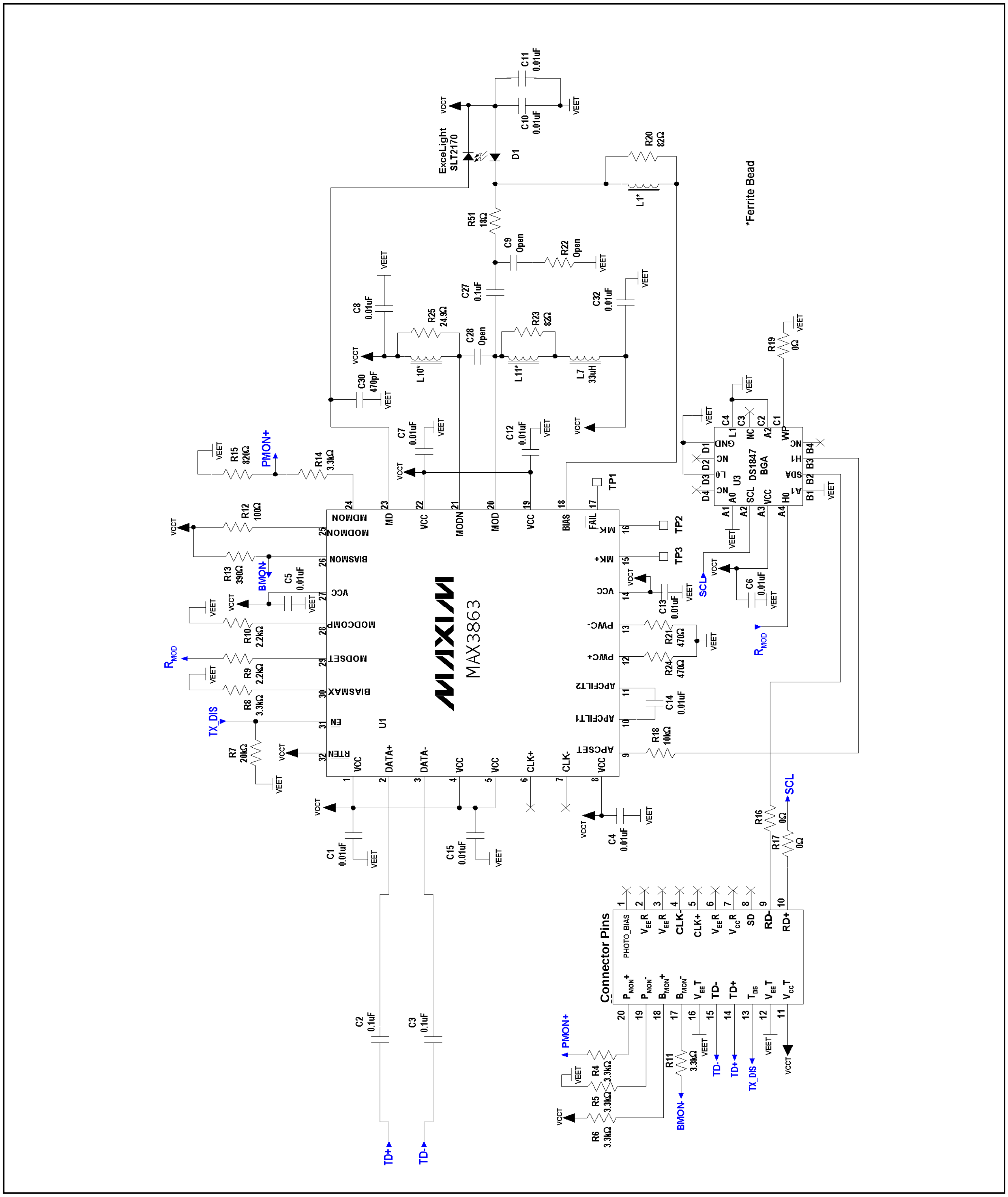


Figure 5. HFRD-2.0A SFF Transmitter Schematic

13 Schematics (Host Board)

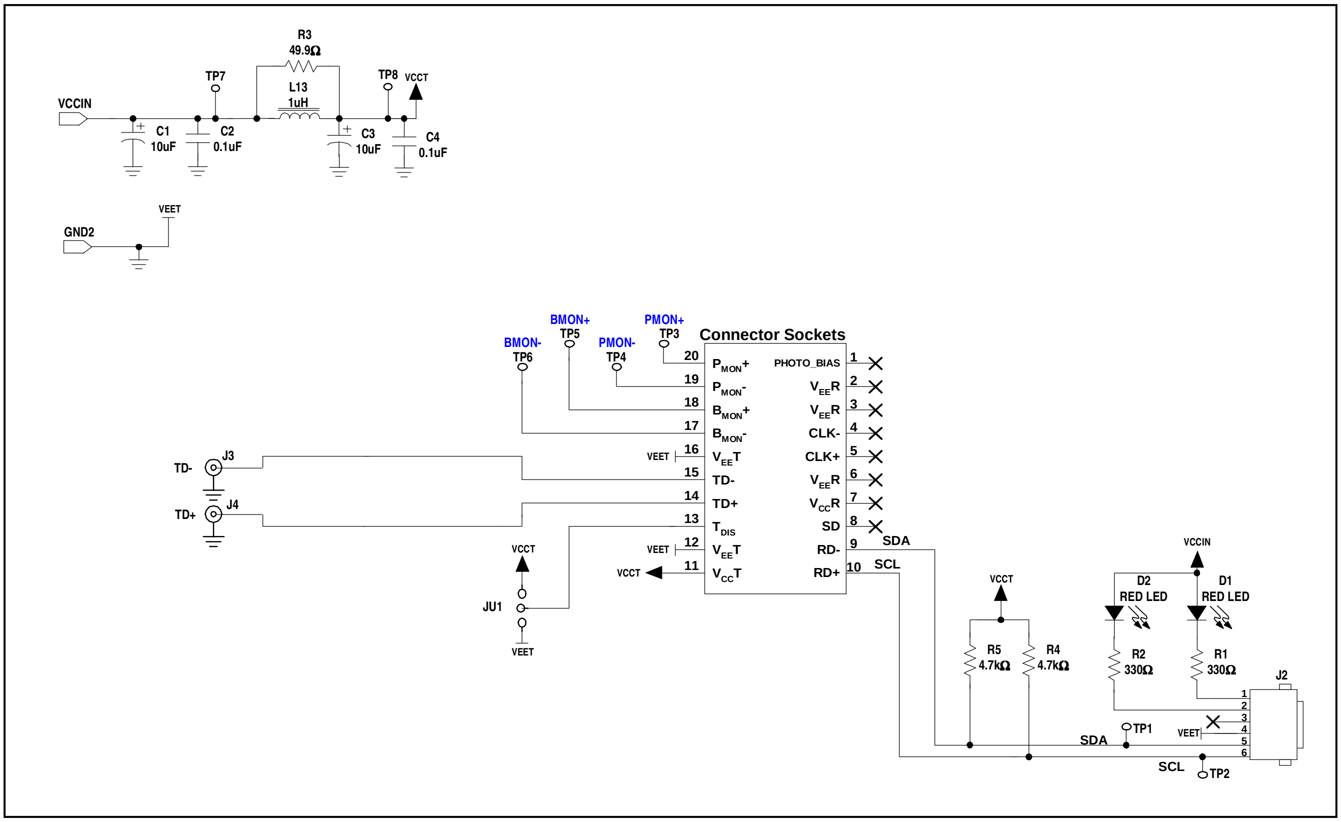
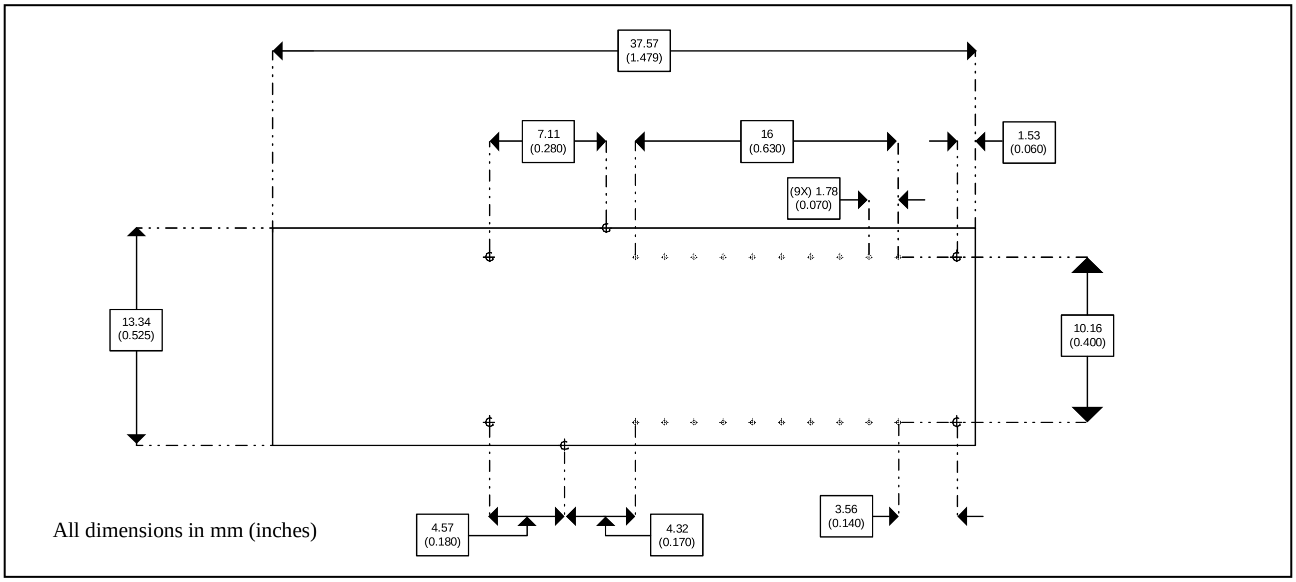


Figure 6. HFRD-2.0B Host Board Schematic

14 SFF Board Dimensions



See SFF MSA for additional dimensions.

15 SFF Board Layout

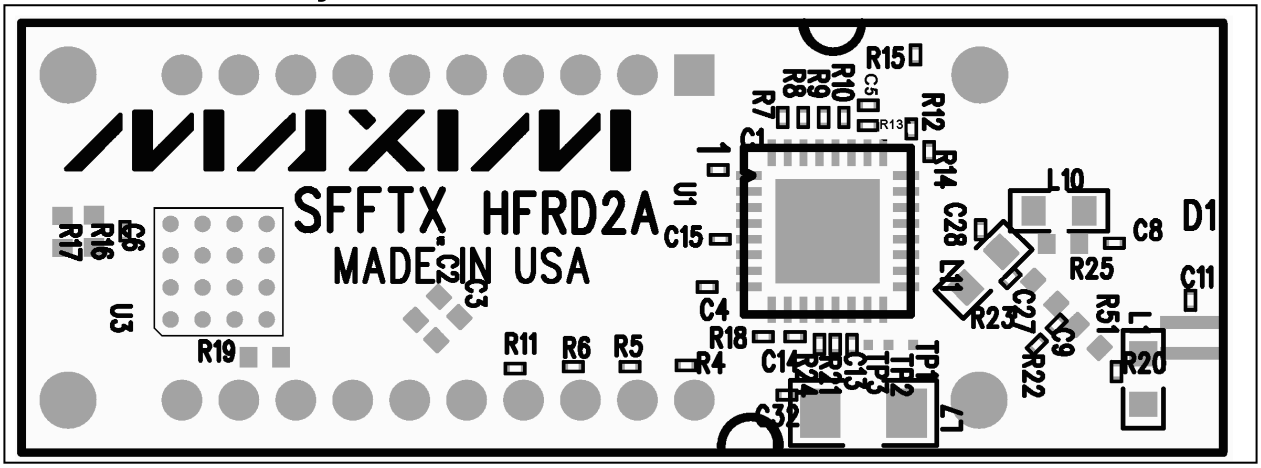


Figure 7: HFRD-2.0A Component Placement Guide – Component Side

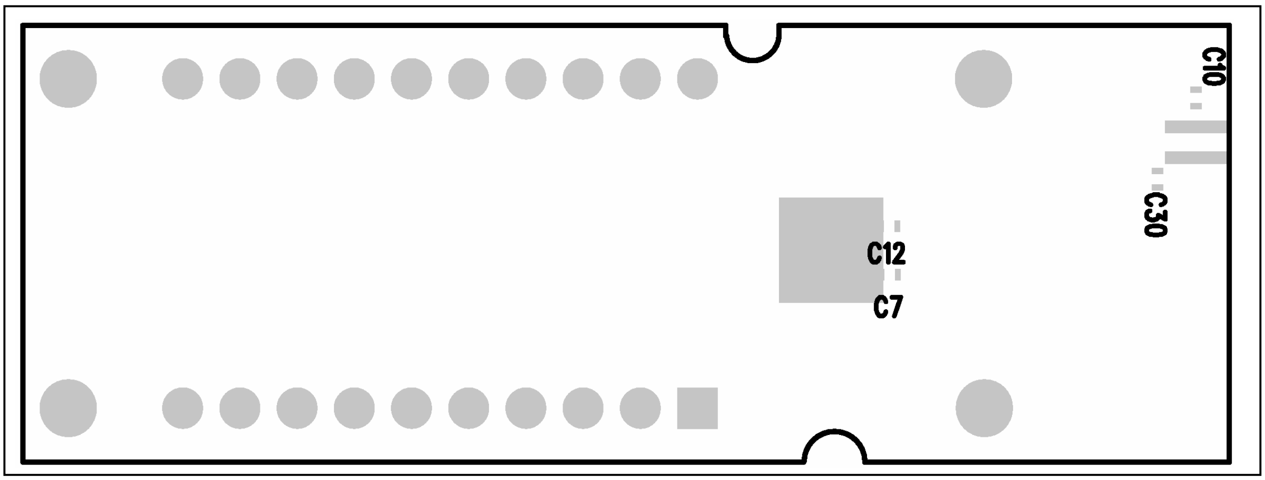


Figure 8: HFRD-2.0A Component Placement Guide – Solder Side

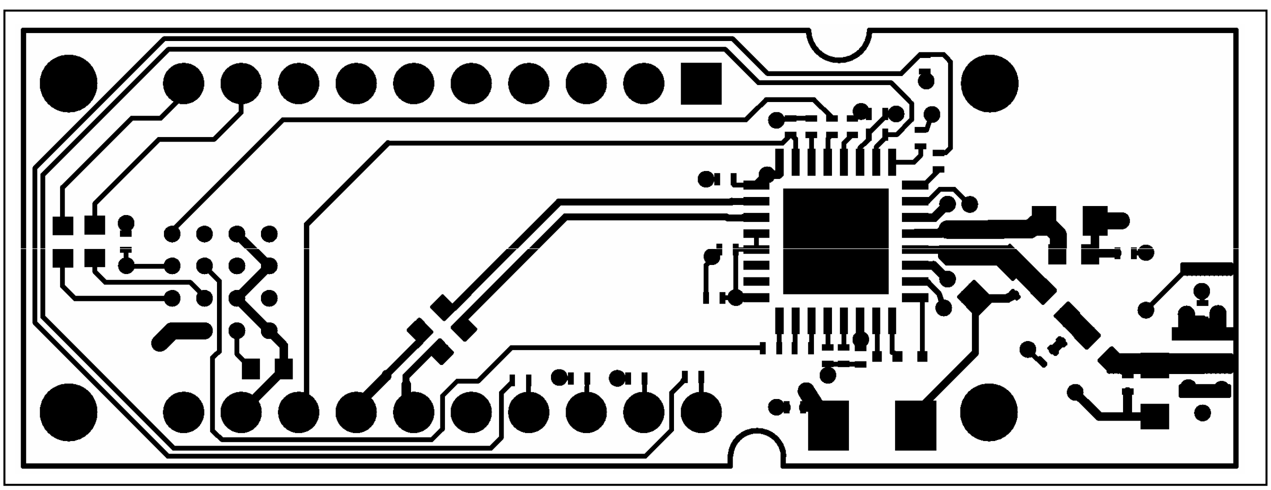


Figure 9: HFRD-2.0A PC Board Layout – Component Side

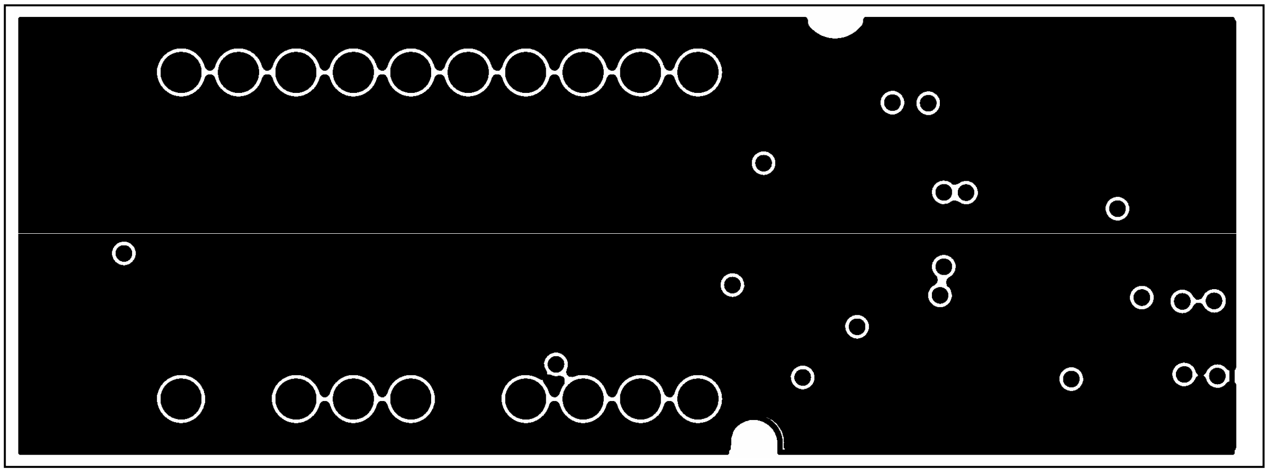


Figure 10: HFRD-2.0A PC Board Layout – Ground Plane

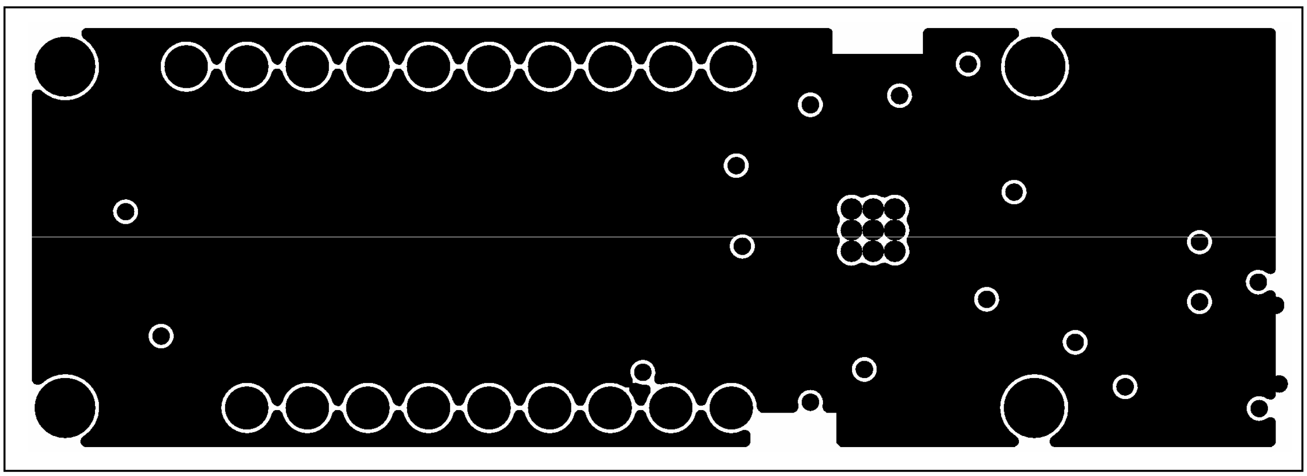


Figure 11: HFRD-2.0A PC Board Layout – Power Plane

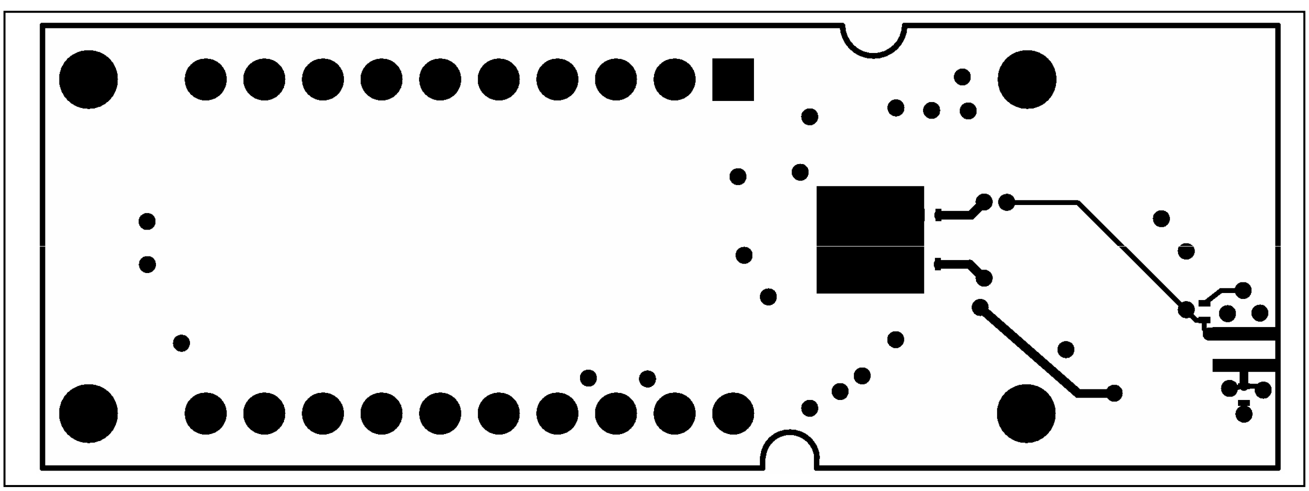


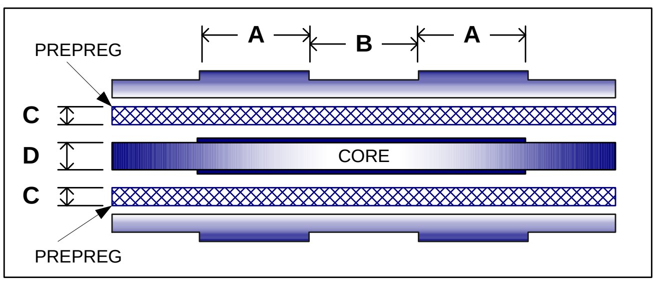
Figure 12: HFRD-2.0A PC Board Layout – Solder Side

16 SFF Layer Profile

This board includes controlled-impedance transmission lines. The layer profile is based on the following assumptions:

1. Dielectric material is FR4 with a dielectric constant of ~ 4.7
2. 1oz copper foil

	SINGLE ENDED	COUPLED
A	11mil	8mil
B	>50mil	10mil
C	8mil	8mil
D	As Needed	As Needed



17 Additional Evaluation Materials

The following materials may be needed to program the DS1847.

1. DS1840K evaluation software: Software that can be run on a standard PC. The software facilitates the interface to the DS1847 digital resistor. Software sends and receives data by communication with the serial port, and the DS9123 serial port dongle.
2. DS9123 Serial Port Dongle: Converts RS232 protocol to 2-wire protocol with appropriate levels. Functions with the software to communicate with the DS1847.
3. Cable (6-Conductor): Reverse-style cable with standard RJ-11 connector that is used to connect the DS9123 serial port dongle to the HFRD-2.0B host board.
4. HFRD-2.0B Reference Design Host Board: Contains plug-in connectors for SFF module as well as high-speed data (SMA) and 2-wire digital communication connectors (RJ-11).

For information regarding items 1-3 please call (972) 371-4076 between 8 a.m. and 5 p.m. central time. For information regarding item 4 call Maxim Integrated Products at (503) 547-2400 between 8 a.m. and 5 p.m. Pacific time.