Infrared Data Association
Serial Infrared Physical Layer
Measurement Guidelines

Version 1.0

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Infrared Data Association SM

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Regards,

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Table of Contents

1. INTRODUCTION

1.1 OBJECTIVE

IrDA compliance relies upon self-certification by equipment developers. This document is intended to assist developers and others by providing recommendations and examples of measurements to determine compliance to the IrDA Serial Infrared Physical Layer Specification and is intended to be used with it and companion documents, the Protocol Test Specification and Implementation Guide For IrDA Compliance. Since many IrDA links are expected to be incorporated in equipment where the link represents a minority of the equipment's value, the intent of this document is to provide examples of inexpensive means and straightforward methods which can be applied at the equipment level and which assume no significant level of optical experience. The measurements described herein are believed sufficient to determine compliance as will be any other set of means and methods which yield equivalent results.

Objectives are:

describe examples of test and measuring circuits,
recommend types of measurement and instrumentation,
recommend calibration,
recommend test procedures,
define terms.

1.2 SCOPE

Measurements described in this document are guidelines for testing the attributes specified in the IrDA Serial Infrared Physical Layer Specification Version 1.1 and are applicable for all data rates in the standard.

Although intended for use at equipment level, these can be used for evaluation of components or subassemblies.

1.3 REFERENCES

The following documents form a part of this specification to the extent specified herein. In case of any conflicts, the content of the IrDA Serial Infrared Physical Layer Specification always takes precedence over this document. Please refer to the various documents for the latest versions.

Infrared Data Association Serial Infrared Physical Layer Link Specification.

Infrared Data Association Serial Infrared Protocol Layer Test Specification.

Infrared Data Association Serial Infrared Link Access Protocol (IrLAP).

IEC Standard Publication 801-3: Electromagnetic Compatibility for Industrial Process Measurement and Control Equipment, Part 3: Radiated Electromagnetic Field Measurements.

1.4 SYMBOLS, ABBREVIATIONS, ACRONYMS AND DEFINITIONS

~	Approximately equal
4PPM	Four Pulse Position Modulation
A	Ampere(s)
BER	Bit Error Ratio
BOF	Beginning Of Frame
cm	Centimeter(s)
CRC16	Cyclic Redundancy Check field associated with a 16 power polynomial.
CRC32	Cyclic Redundancy Check field associated with a 32 power polynomial.
DUT	Device Under Test
EOF	End Of Frame
Fall Time	An attribute that describes the high state to low state transition time of a signal, herein the time from the 90% point to the 10% point of the transition.
Far Field	The region in which the irradiance follows an inverse square relationship with the distance to the source.
FFS	Far Field Infrared Source: The name of a test circuit used herein as an IR source of IrDA signals for far field measurements.
Iled	LED Current: used herein as a label for the LED current in various test circuits.
Intensity	An attribute that describes flux per unit solid angle radiating from a finite area source, herein expressed as watts per steradian, W/sr.
IR	Infrared
IrDA	Infrared Data Association
IrLAP	Infrared Data Association Serial Infrared Link Access Protocol
Irradiance	An attribute that describes flux per unit area on a reception surface, herein expressed as watts per square centimeter, W/cm^2.
Jitter	An attribute that describes the range of deviation of time positions between a signal edge and its reference or expected position.
kb/s	Kilobit(s) per second
LED	Light Emitting Diode
µF	Microfarad(s)
µs	Microsecond(s)
µW	Microwatt(s)
mA	milliampere(s)
Mb/s	Megabit(s) per second
mm	Millimeter(s)
mW	Milliwatt(s)
Near Field	The region near the source in which the irradiance does not follow an inverse square relationship with the distance to the source.
NFS	Near Field Infrared Source: The name of a test circuit used herein as an IR source of IrDA signals for near field measurements.
nm	Nanometer(s)
ns	Nanosecond(s)
OVC1	Optical Power to Voltage Converter 1: The name of a test circuit used herein for measuring amplitude of infrared pulses.
OVC2	Optical Power to Voltage Converter 2: The name of a test circuit used herein for measuring temporal characteristics of infrared pulses.

pF	picofarad(s)
Photodiode	A semiconductor diode exhibiting photoresponse.
PIN	A semiconductor with adjoining layers of P-type material, intrinsic material and N-type material
Responsivity	An attribute that describes photodiode response, herein expressed as photocurrent per unit radiant flux, A/W.
RFI	Radio Frequency Interference
Rise Time	An attribute that describes the low state to high state transition time of a signal, herein the time from the 10% point to the 90% point of the transition.
SFS	Simulated Fluorescent Lighting Source: The name of a test circuit used herein as an IR source of the IrDA simulated fluorescent lighting ambient interference condition.
SIR	Serial Infrared
sr	Steradian
SSS	Simulated Sunlight Source: The name of a test circuit used herein as an IR source of the IrDA simulated sunlight ambient interference condition.
STA	Start Flag
Steradian	Units of solid angle, where 4π steradians are included in a unit sphere.
STO	Stop Flag
tf	fall time(s)
tr	rise time(s)
V	Volt(s)
Vamptd	Voltage amplitude: used herein as an attribute that describes the difference between a statistical maximum level and statistical minimum level of a pulse.
Vcc	A label for the supply voltages of various test circuits.
Viled	LED Current Sense Voltage: used herein as a label for the signals developed across current sensing resistors to monitor LED current in various test circuits.
Vin	Input Voltage: used herein as a label for the input signals of various test circuits.
Vleda	LED Anode Voltage: used herein as a label for the signals developed at the anode of the LED in various test circuits.
Vmax	Voltage maximum: used herein as an attribute that describes the positive peak level of a pulse.
Vo	Output Voltage: used herein as a label for the output signals of various test circuits.
Vtop	Voltage top: used herein as an attribute that describes a statistical maximum level of a pulse.
W	Watt(s)
X'YZ'	Byte representation in hex form, herein of the form X'YZ' where a byte is represented with two hex digits with the least significant four bits on the right, Z, and the most significant four bits on the left, Y.

2. MEASUREMENT MEANS

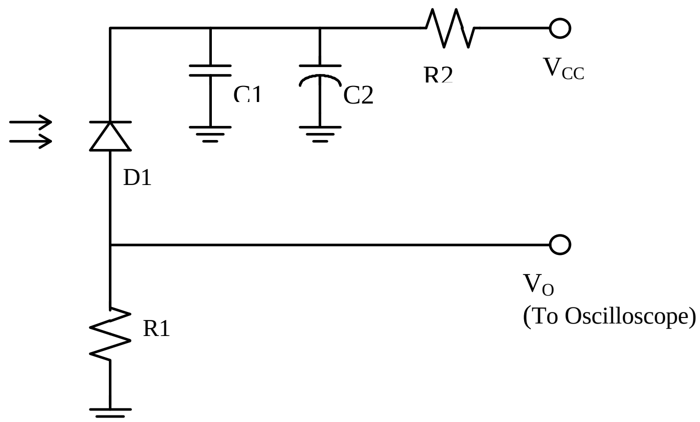
The strategy in the following set of measurements is to use PIN photodiodes as infrared power to current transducers and to use the capabilities of a digitizing oscilloscope for any measurement of electrical and temporal quantities. This calls for one well-calibrated PIN diode which can be use to calibrate the other infrared sources or detectors. In addition, measurements are generally made in pulse mode which better represents end use and provides the advantages of improving resistance to ambient interference.

The various LED IR sources are expected to have significant temperature dependencies and, consequently, it's important that self-heating be avoided or minimized, especially when LED currents are greater than 50 mA. To this end, pulse widths and duty cycles are kept small. Even when data patterns call for 3/16 or 25% duty cycles, the patterns should be sent in bursts with gaps between patterns sufficient to reach an overall 1% duty cycle.

2.1 TEST CIRCUITS

2.1.1 INFRARED CONVERTER - CALIBRATED AMPLITUDE: OVC1

Figure 2.1.1A shows a schematic for an optical power to voltage converter (OVC1) suitable for measuring amplitude of infrared pulses from which irradiance or intensity can be derived. A PIN photodiode, D1, is used to convert optical power to current which is transformed to a voltage by resistor, R1 (R1 includes input impedance of oscilloscope probe.). The output, Vo, is an analog of the optical signal. Stray capacitance loading this node should be minimized to maintain short rise and fall times. Capacitors, C1 and C2, and resistor, R2, are used to filter the supply voltage. Photodiode, D1, is the essential component and must be well calibrated for responsivity in $A/(W/cm^2)$ or in A/W and have a well defined area. This circuit is fundamental to physical layer testing and once calibrated will be used to calibrate the other test circuits. When implemented with suitable components and used with an appropriate oscilloscope, OVC1 should be adequate to measure the amplitude of infrared pulses wider than 1.4 µs at 20 to 30 cm from a 40 mW/sr source. See example below.



OVC1: Optical Power To Voltage Converter

Figure 2.1.1A

The output voltage, Vo, is related to the light incident on the photodiode, Irradiance, by the relationship

$$Vo = Irradiance \times Area(Photodiode) \times Responsivity(Photodiode) \times R1.$$

The gain, Vo/Irradiance, for this circuit can be expressed as

$$Vo/Irradiance = Area(Photodiode) \times Responsivity(Photodiode) \times R1.$$

Irradiance, in the far field, is related to Intensity by the expression

$$Irradiance = Intensity/(Distance)^2.$$

2.1.1.1 OVC1 AMPLITUDE CALIBRATION

The following describes calibration of OVC1. This procedure will determine calibration constants used in irradiance and intensity measurements.

Irradiance calculations require values for R1 and the responsivity and optically sensitive area of the photodiode, either combined as $A/(W/cm^2)$ or separately as A/W and Area. To convert irradiance to intensity, the distance to the source must be known. The relationship used to convert irradiance to intensity requires that measurements be made where the photodiode is in the source's far field, that is, where irradiance declines with the square of the distance to the source.

1. Determine active area and responsivity of D1 for the wavelength range of 850 to 900 nm.

2. Determine the resistance of R1, including the effects of any load, e.g. oscilloscope input impedance.

3. The output voltage, Vo, is related to the light incident on the photodiode, Irradiance, by the relationship

$$Vo = Irradiance \times Area(Photodiode) \times Responsivity(Photodiode) \times R1.$$

Irradiance can be expressed as

$$Irradiance = Vo / (Area(Photodiode) \times Responsivity(Photodiode) \times R1)$$

And, Intensity can be expressed as

$$\begin{aligned} Intensity &= Irradiance \times Distance^2 \\ &= (Vo \times Distance^2)/ Area(Photodiode) \times Responsivity(Photodiode) \times R1 \end{aligned}$$

Where Responsivity is expressed in $A/(W/cm^2)$, these expressions become

$$Irradiance = Vo / Responsivity(Photodiode) \times R1$$

and

$$Intensity = (Vo \times Distance^2)/ Responsivity(Photodiode) \times R1.$$

2.1.1.2 OVC1 EXAMPLE IMPLEMENTATION

Table 1: Example OVC1 (See Figure 2.1.1A.**)**

D1	UDT 10D Optically Sensitive Area = 1.00 cm^2 Typical Responsivity (850 to 900 nm) = 0.5 A/W Typical Cpin(10V) = 300 pF Minimum Breakdown Voltage = 50 V Typical tr & tf = 25 ns (for 50 Ohms and 50 V)
R1	500 Ohm, ± 1%, 0.25 W, Includes oscilloscope input impedance.
R2	10 Ohm, ± 5%, 0.25 W
C1	0.1 µF, ± 20%, 50 V, Z5U or X7R
C2	22 µF, ± 20%, 35 V, Ta or Al
Vcc	27 V
Oscilloscope	HP 54542A

This example circuit with components listed in Table 1 when used with a oscilloscope with a 1mV/divison vertical sensitivity should be adequate to measure the amplitude of infrared pulses of 1.4 µs width at 20 to 30 cm from a 40 mW/sr source. To achieve good results with the oscilloscope, use a 1x probe and the most sensitive vertical scale available where the signal is not clipped. Where available use the Vamptd measurement function (instead of peak-to-peak measurements) and the filter and statistics functions of the oscilloscope to reduce the effect of noise in the measurement.

For this example and with a Vcc of 27 Volts, Vo(OVC1) rise and fall times were less than 400 ns and did not significantly limit the signal amplitude. With a Vcc of 9 volts, the rise and fall times of Vo were larger than 600 ns and affected the amplitude measurement by 5%. If rise and fall times are greater than 500 ns, an increase in Vcc may be sufficient to improve performance, otherwise reduce the value of R1.

From the data sheet for D1, UDT 10D, the active area is a circular area of 1.0 cm^2. From the certification of calibration supplied by vendor for this individual unit,

Wavelength nm	Responsivity A/W
850	0.5880
860	0.5947
870	0.6012
880	0.6067
890	0.6120
900	0.6178

the average responsivity over the 850 through 900 nm range is 0.6034 A/W.

Caution: Responsivity will differ from unit to unit and must be calibrated on an individual basis.

An in-circuit measurement of R1, with Vcc disconnected, yielded a 500 Ohms result.
Irradiance can be calculated as a function of Vo, yielding

Irradiance = Vo / (Area(Photodiode) x Responsivity(Photodiode) x R1)

Irradiance = Vo / (1.0 cm^2 x 0.6034 A/W x 500 Ohms)

= Vo x (3.31 mW/V)/ cm^2.

The gain, Vo/Irradiance, for this example circuit is given by

Vo/Irradiance = Area(Photodiode) x Responsivity(Photodiode) x R1.

= (1.0 cm^2) x (0.6034 A/W) x (500 Ohms)

Vo/Irradiance = 0.302 mV/(μW/cm^2).

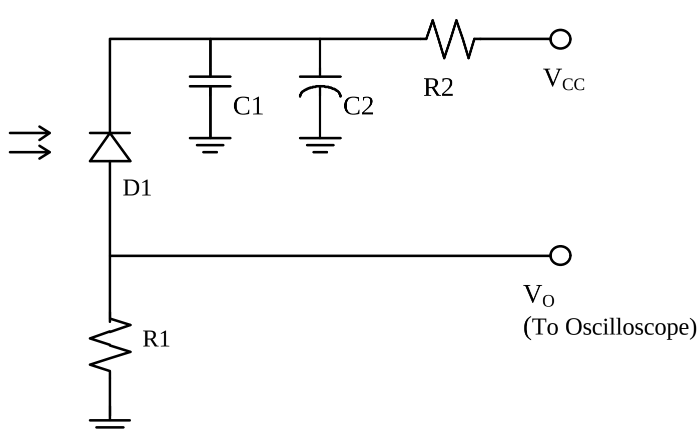
Irradiance at 20 cm from a 40mW/sr source is given by

Irradiance = Intensity/$(\text{Distance})^2$ = (40mW/sr)/$(20\text{cm})^2$ = 100 μW/cm^2,

yielding an output, Vo, with an amplitude of 30.2 mV, which should be easily measured.

2.1.2 INFRARED CONVERTER - WIDE BANDWIDTH: OVC2

Figure 2.1.2A shows a schematic for an optical power to voltage converter, OVC2, suitable for measuring temporal characteristics of infrared pulses. A PIN photodiode, D1, is used to convert optical power to current which is transformed to a voltage by resistor, R1 (R1 becomes the 50 Ohm oscilloscope input impedance.). The output, Vo, is an analog of the optical signal. Stray capacitance loading this node should be minimized to maintain short rise and fall times. Capacitors, C1 and C2, and resistor, R2, are used to filter the supply voltage. To maintain wideband performance (signals can easily have 10 ns rise and fall times), use 50 Ohm coax cable to connect Vo to the oscilloscope, terminate the coax with the 50 Ohm oscilloscope input option and avoid impedance mismatches. When implemented with suitable components (see example below) and used with an appropriate oscilloscope, OVC2 should be adequate to measure pulse widths equal to or wider than 115 ns and rise and fall times equal to or shorter than 40 ns for infrared pulses at 3 to 8 cm from a 40 mW/sr source. OVC2 should yield symmetrical rise and fall times.



OVC2: Wideband Optical Power To Voltage Converter

Figure 2.1.2A

A basic premise is that pulse widths and rise and fall times are not dependent on angle or affected by the media. The rise time, tr(Vo), of the output signal, Vo, is approximately related to the rise time, tr(Irradiance) of the Irradiance and the response time of the circuit, tr(OVC2), by the expression

$$tr(Vo)^2 \sim tr(Irradiance)^2 + tr(OVC2)^2.$$

And,

$$tr(OVC2) \sim [tr(Vo)^2 - tr(Irradiance)^2]^{0.5}$$

The approximation is valid when the terms are dominated by single time constants.

Use for relative amplitude measurements assumes relative spacial pattern is constant with pulse width so a ratio of amplitudes can be established between a near field and a far field measurement which will be invariant with pulse width. This permits using OVC2 in the near field where it can yield a strong signal to monitor amplitude of IR pulses with widths too narrow for OVC1.

2.1.2.1 OVC2 TEMPORAL CALIBRATION

The following describes the calibration of OVC2 for rise and fall times Use the fastest optical source available to check for a smooth response with no overshoot due to the detector circuit..

To calibrate this circuit for rise and fall times, an IR source within the IrDA wavelength range of 850 nm to 900 nm and with known rise and fall times (< 40 ns or known to be < 9 ns) is required.

1. Determine rise and fall time of a fast IR (850 nm < peak wavelength < 900 nm) test source. Rise and fall times < 40 ns or known to be < 9 ns are required.

2. Measure rise time of OVC2 output, Vo, using the fast IR source from Step 1. An optical source with a rise time less than 40 ns is sufficient. The rise time, tr(Vo), of the output signal, Vo, is related to the rise time, tr(IR) of the irradiance and the response time of the circuit, tr(OVC2), by the expression

$$tr(Vo)^2 \sim tr(IR)^2 + tr(OVC2)^2.$$

And

$$tr(OVC2) \sim [tr(Vo)^2 - tr(IR)^2]^{0.5}.$$

The approximation is valid when the terms are dominated by single time constants.

3. Repeat step 2 for fall times. OVC2 should yield fairly symmetrical rise and fall times.

2.1.2.2 OVC2 EXAMPLE IMPLEMENTATION

Table 2: Example OVC2 (See Figure 2.1.2A.**)**

D1	Temic BPV23NF (or Thorlabs DET200) Typical Optically Sensitive Area = 5.7 mm^2 Typical Responsivity (870 nm) = 0.57 A/W Typical Cpin(0V) = 48 pF Minimum Breakdown Voltage = 60 V Typical tr & tf (Vr = 10 V, Rl = 1 kOhms, Wavelength = 820 nm) = 70 ns
R1	50 Ohm, Use oscilloscope 50 Ohm input.
R2	10 Ohm, ± 5%, 0.25 W
C1	0.1 µF, ± 20%, 50 V, Z5U or X7R
C2	22 µF, ± 20%, 50 V, Ta or Al
Vcc	50 V
Oscilloscope	HP 54542A
IR Source	BCP Laser Transmitter: Model 400

This example circuit with components listed in Table 2 when used with an oscilloscope with a 50 MHz bandwidth and a 1mV/divison vertical sensitivity should be adequate to measure infrared pulses of 115 ns width and 40 ns rise and fall times at 3 to 8 cm from a 40 mW/sr source. The Temic photodiode has acceptable rise and fall times with large reverse bias, reasonable sensitivity and incorporates a filter for less than IR wavelengths. The Thorlabs photodiode offers rise and fall times less than 1 ns but provides a small active area and may require a secondary lens for satisfactory use.

A 50 Ohm coax cable was used to connect Vo(OVC2) to the oscilloscope and the 1x, 50 Ω input option was selected. The rise and fall time measurement functions and the statistics function of the oscilloscope were selected. In this case the averaging function did not appear necessary and the pulse amplitude did not appear limited by the rise time of the signal.

From the IR source (BCP Laser Transmitter: Model 400) data sheet, pulse rise and fall times are less than or equal to 0.5 ns and from the product label the wavelength is 870 nm.

For an IR pulse waveform with a 1.0 µs period and a 125 ns pulse width and a Temic BPV23NF for the photodiode, D1, Vo provided the following rise and fall times.

Vcc (V)	Rise Time (ns)	Fall Time (ns)
27	13.3	22.9
40	9.8	10.1
50	8.3	8.6

The rise time of OVC2 (Vcc = 50 V) was derived from

$$tr(OVC2) \sim [tr(Vo)^2 - tr(IR)^2]^{0.5}$$
$$\sim [(8.3\ ns)^2 - (0.5\ ns)^2]^{0.5} = 8.28\ ns.$$

Similarly, the fall time of OVC2 (Vcc = 50 V) was calculated as

$$tf(OVC2) \sim [(8.6\ ns)^2 - (0.5\ ns)^2]^{0.5} = 8.59\ ns.$$

Note, for an IR source with rise and fall times of 40 ns, this implementation of OVC2 will provide

$$tr(Vo) \sim [(8.28\ ns)^2 + (40\ ns)^2]^{0.5} = 40.8\ ns$$

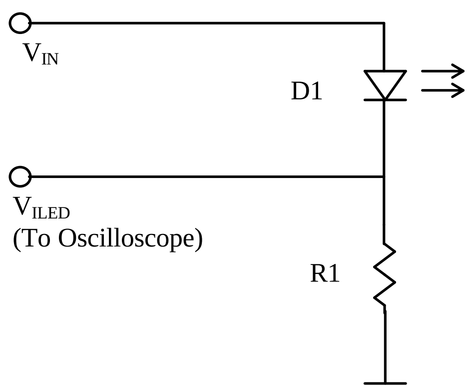
and

$$tf(Vo) \sim [(8.59\ ns)^2 + (40\ ns)^2]^{0.5} = 40.9\ ns.$$

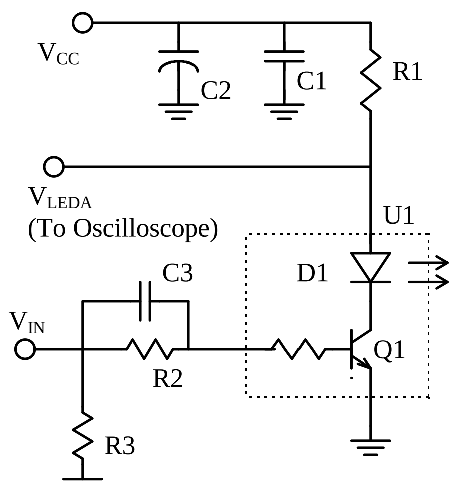
2.1.3 INFRARED FAR FIELD SOURCES: FFS

Figure 2.1.3A shows schematics for infrared sources, FFS-A and FFS-B, suitable as a sources for far field tests, e.g. receiver sensitivity. FFS-A provides easy control of the optical signal rise and fall times and is used where the rise and fall times are desired to be set at 600 ns. FFS-B provides faster optical signal edges and is used where rise and fall times are desired to be set at 40 ns or less. FFS-B can also be implemented with the transmitter from a variety of available IrDA transceiver modules or with a copy of the Near Field Infrared Source described below.

In both circuits an LED, D1, is used to convert current into IR power and the voltage developed across resistor R1 is an analog of the LED current and IR power. In FFS-A, the 50 Ohm oscilloscope input impedance can be used for resistor R1 and 50 Ohm coax cable used for connection to minimize impedance mismatches. In FFS-B capacitors, C1 and C2, are used to bypass impedance in the Vcc supply and reduce supply droop during the turn-on transition. Input network R2 and C3 is a peaking circuit to minimize transistor Q1's turn-on and turn-off transition times and minimize pulse width distortion due to saturation or charge storage in Q1. (The peaking circuit may not be required with all implementations.) Resistor, R3, is used to terminate the cable from the pulse generator providing Vin. LED current pulse amplitudes should be kept low (< 200 mA) and overall duty cycle should be kept low (~ 1%) to avoid self- heating effects.



FFS-A: Far Field Infrared Source -A



FFS-B: Far Field Infrared Source -B

Figure 2.1.3A

Amplitude calibration can be done with the above infrared converter, OVC1. Rise and fall times and pulse widths can be checked with the above wide bandwidth converter, OVC2. Test source timing attributes, data pattern, signaling rate, pulse width and jitter, are determined by the pulse generator driving Vin. A two channel pulse generator can induce jitter by generating some of the data pattern in each channel, setting a delay between channels to produce the desired jitter at the switchover point(s) in the pattern and combining the channel outputs to produce the entire pattern.

A copy of FFS-B can be used to generate the fluorescent lighting interference signal. This circuit is preferred to FFS-A for its expected faster rise and fall times.

An option for an infrared source is to calibrate a transmitter in the equipment being evaluated or any IrDA compliant equipment. (Primary implementations are preferable.) This has the advantage of access to the protocols and framing required to establish a link, negotiate data rates and facilitate file transfers which simplifies BER tests. The disadvantages include the limited ability to control pulse widths and rise and fall times. This option works best with a minimum or sub-minimum intensity transmitter and a better than minimum receiver, in the test source, to ensure the test link is limited by the receiver in the equipment under test.

2.1.3.1 FFS CALIBRATION

OVC1 may not have the sensitivity to accurately measure signal levels in the 4 to 10 $\mu W/cm^2$ range. Consequently, this calibration establishes a relationship between irradiance at near and far field distances from the test source and the associated LED current levels and determines the LED current needed to provide irradiance of 4 $\mu W/cm^2$ and 10 $\mu W/cm^2$ at the far field point. Within the far field, then, either distance or drive current can be used to vary the irradiance. If a source is used where the drive current to the LED cannot be monitored or adjusted, then, distance can be used to vary the irradiance. Measurements are recommended with short pulse widths, ≤ 10 μs, and a low duty cycle, ~1%, pattern to minimize self heating. For the example circuits, it's recommended that the far field distance be chosen such that the LED currents for the 4 $\mu W/cm^2$ and 10 $\mu W/cm^2$ calibration points are in the 5 mA to 200 mA range.

1. Arrange the FFS and OVC1 to be on-axis with a convenient near field distance, approximately 5 cm. Monitor the LED current, I_{LED} (where I_{LED} = delta V_{ILED}/R1 for FFS-A or delta V_{LEDA}/R1 for FFS-B), with an oscilloscope. Set a pulse generator to provide the input signal, Vin, with a Pulse Width = 1.4 to 10 μs and a Duty Cycle = 1%. Check the waveforms at V_{ILED} for FFS-A or V_{LEDA} and Vo(OVC1) for FFS-B to see they are reasonably smooth and not limited by the rise and fall times. Allow time for temperature to stabilize as LEDs can have significant temperature dependencies.

2. Use OVC1 to measure irradiance for I_{LED} at several increments between 5 mA or 10 mA and 200 mA to 500 mA. The relationship between irradiance and I_{LED} should be reasonably linear.

3. Leaving I_{LED} at the highest current, move OVC1 to a convenient far field distance, 30 cm to 50 cm from FFS, maintaining on-axis alignment, and measure irradiance. (If the output isn't strong enough for clean measurements, move to a shorter distance. It should not be necessary to use higher than 500 mA.) Calculate the ratio of irradiance in the near field distance to that in the far field distance.

4. Use the ratio established between the near and far field measurements and interpolate between measurements taken at low currents in the near field to calculate the LED current to provide 4.0 $\mu W/cm^2$ and 10.0 $\mu W/cm^2$ for this far field distance.

5. With FFS-A, arrange OVC2 at a convenient point and use it to observe the optical waveform

and set the LED current to that determined in Step 4 for 4 .0 μW/cm^2. Adjust the pulse generator to provide an optical signal pulse width of 1.4 μs with rise and fall times of 600 ns. Adjust the pulse generator as necessary to maintain a constant amplitude of the LED current waveform and the optical signal. There should be no overshoot in the optical waveform. These are the conditions to produce the minimum optical signal for receiver tests at data rates of 115.2 kb/s or less.

6. With FFS-B, set the LED current to that determined in Step 4 for 10.0 μW/cm^2. Note the IR pulse amplitude on Vo(OVC2); OVC1 may not have the bandwidth for pulse widths < 1μs. Adjust the pulse generator to provide an optical signal pulse width of 115 ns with rise and fall times of 40 ns. Adjust the pulse generator or FFS supply voltage as necessary to maintain a constant amplitude of the LED current waveform and the optical signal. There should be no overshoot in the optical waveform. These are the conditions to produce the minimum optical signal for receiver tests at 4 Mb/s, 4PPM. For 576 kb/s and 1.152 Mb/s signals, amplitude and rise and fall times remain the same and the pulse widths are adjusted to 295.2 ns and 147.6 ns, respectively.

2.1.3.2 FFS EXAMPLE IMPLEMENTATION

Table 3: FFS Examples (See Figure 2.1.3A.**)**

	FFS-A
D1	HSDL-4220 (or GL551, TSHA550)
R1	50 Ohm, Use oscilloscope 50 Ohm input.
Oscilloscope	HP 54542A
Pulse Generator	HP 8110A

	FFS-B
U1	HSDL-1100 (or GL1F20, HRM200S, TFDS6000, MiniSIR)
R1	10 Ohm,± 1%, 0.5 W
R2	560 Ohm, ± 5%, 0.25 W
R3	50 Ohm, ± 5%, 0.25 W
C1	0.1 μF, ± 20%, 15 V, Z5U or X7R
C2	22 μF, ± 20%, 15 V, Ta or Al
C3	220 pF, ± 10%, X7R
Vcc	1.5 to 5.0 V
Oscilloscope	HP 54542A
Pulse Generator	HP 8110A

The FFS-A example circuit with components listed in Table 3 should be able to generate IR pulses with an irradiance levels of 4 μW/cm^2 at distances up to 50 cm, pulse widths ≥ 1.4 μs and rise and fall times of 600 ns. The FFS-B example circuit with components listed in Table 3 should be able to generate IR pulses with an irradiance levels of 10 μW/cm^2 at distances up to 50 cm, pulse widths ≥ 115 ns and rise and fall times ≤ 40 ns.

For the FFS-A example circuit, a pulse generator was set to provide the input signal, Vin, as follows: Low State = 0.0 V, Pulse Width = 5 μs, Duty Cycle = 1%. The pulse generator High State was set to provide the desired LED current as measured at R1. The waveforms at

VILED(FFS-A) were reasonably smooth, not limited by the rise and fall times and quickly stabilized. The supply, Vcc, of OVC1 was increased to 18 V to accommodate the high irradiance levels.

The example implementations of FFS-A and OVC1, on axis at 5, 20 and 30 cm separation, provided the results in the following table of irradiance and LED current. LED current was derived from the signal VILED and resistor, R1, and Irradiance was derived from the output, Vo, of OVC1, where

Irradiance = Vo x (3.31 mW/V)/ cm^2. See Section 2.1.1.2 OVC1 Example.

Distance (cm)	5	5	5	5	5	5	20	30
LED Current (mA)	5	10	20	40	80	190	190	190
Vo (OVC1) (mV)	30.3	63.1	129.0	257.8	525	1250	101.9	46.3
Irradiance ($\mu W/cm^2$)	100.3	208.9	427	853	1738	4138	337	153.1
Intensity (mW/sr)						103	135	138

This provided a near field (5 cm) to far field (30 cm) ratio of 27.03. With this ratio the irradiance at 30 cm and low drive currents were determined as follows.

Distance (cm)	30	30	30	30	30	30
LED Current (mA)	5	10	20	40	80	190
Irradiance ($\mu W/cm^2$)	3.71	7.73	15.8	31.6	64.3	153

Interpolating between LED currents of 5 and 10 mA, yielded 5.36 mA as the LED current required for $4uW/cm^2$ at 30 cm.

For data rates ≤ 115.2 kb/s, Vin was adjusted to provide LED current of 5.36 mA yielding 4 $\mu W/cm^2$ at 30 cm. OVC2 was set within 3 to 5 cm of FFS and slightly off axis so as not to disrupt the link between the FFS and OVC1. The pulse generator was adjusted (Pulse Width = 1.4 µs, Period = 8.68 µs, tr = 610 ns and tf = 610 ns) to produce a 1.4 µs pulse width with rise and fall times of 600 ns. Outputs of OVC1 and OVC2 were checked to see that the pulse amplitudes were not affected. These became the conditions for checking receiver sensitivity at data rates ≤ 115.2 kb/s. The pulse generator was set to produce a pattern with a data burst of 2 ms and a gap between bursts of 30 ms for an overall duty cycle ≤ 1%.

For the FFS-B example circuit, a pulse generator was set to provide the input signal, Vin, as follows: Low State = 0.0 V, High State = 3.0 V, Pulse Width = 5 µs, Duty Cycle = 1%. Set Vcc = 3.0 V. The waveforms at VLEDA(FFS) and Vo(OVC1) were reasonably smooth, not limited by the rise and fall times and quickly stabilized. The supply, Vcc, of OVC1 was increased to 18 V to accommodate the high irradiance levels.

The example implementations of FFS-B and OVC1, on axis at 5, 20 and 30 cm separation, provided the results in the following table of irradiance and LED current. LED current was derived from the signal VLEDA and resistor, R1, and Irradiance was derived from the output, Vo, of OVC1, where

Irradiance = Vo x (3.31 mW/V)/ cm^2. See Section 2.1.1.2 OVC1 Example.

Distance (cm)	5	5	5	5	5	20	30
LED Current (mA)	10	30	100	200	500	500	500
Vo (OVC1) (mV)	50.4	152.9	518.0	1027	2544	156.8	70.1
Irradiance ($\mu W/cm^2$)	166.8	506.1	1715	3399	8421	519	232
Intensity (mW/sr)						208	209

This provided a near field (5 cm) to far field (30 cm) ratio of 36.3. With this ratio the irradiance at 30 cm and low drive currents were determined as follows.

Distance (cm)	30	30	30	30	30
LED Current (mA)	10	30	100	200	500
Irradiance ($\mu W/cm^2$)	4.60	13.95	47.25	93.67	232.03

Interpolating between 10 mA and 30 mA, yielded 21.6 mA as the LED current for 10 $\mu W/cm^2$ at 30 cm.

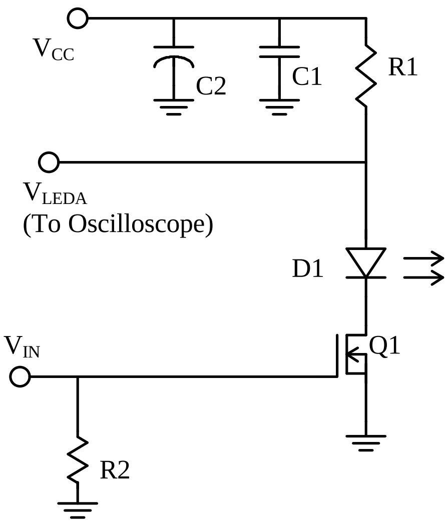
For data rates ≥ 115.2 kb/s, Vcc was adjusted to provide LED current of 21.6 mA yielding 10 $\mu W/cm^2$ at 30 cm. OVC2 was set within 3 to 5 cm of FFS-B and slightly off axis so as not to disrupt the link between the FFS and OVC1. The pulse generator was adjusted (Low State = 0.0 V, High State = 3.0 V, Pulse Width = 125 ns, Period = 500 ns, tr = 19.9 ns and tf = 12.5 ns) to produce a 115 ns pulse width with rise and fall times of 40 ns. The pulse amplitude of OVC2 has not been affected. These became the conditions for checking FIR receiver sensitivity. The pulse generator is set to produce a pattern with a data burst of 64 µs and a gap between bursts of 448 µs for an overall duty cycle of 2.3%. At LED currents less than 50 mA, self heating should be low enough to tolerate duty cycles greater than 1%.

2.1.4 INFRARED NEAR FIELD SOURCE: NFS

Figure 2.1.4A shows a schematic for an infrared source, NFS, suitable for near field tests. An LED, D1, is used to convert current into IR power. The voltage developed across resistor R1 is an analog of the LED current and IR power. Capacitors, C1 and C2, are used to bypass impedance in the Vcc supply and reduce supply droop during the turn-on transition. Resistor, R2, is used to terminate the cable from the pulse generator providing Vin. Since LED current pulse amplitudes can be high (500 mA to 1 A), overall duty cycle should be kept low (~ 1%) to avoid self- heating effects.

Amplitude calibration can be done with the above infrared converter, OVC1. At high irradiance levels some adjustment of OVC1 (e.g. Vcc and R1) may be necessary. Check for suitable rise and fall times and pulse widths with the above wide bandwidth converter, OVC2. Keep overall duty cycle low (~ 1%) to avoid self- heating effects.

Reaching 500 mW/cm^2 may require working distances of 1 cm or less. At these short distances the intensity may not be uniform over the active detector area of OVC1 and it is recommended to limit the power to that incident on the active area of the optical port under test. Calibrate the NFS through an aperture that matches the expected active area of the DUT's receiver.



NFS: Near Field Infrared Source

Figure 2.1.4A

2.1.4.1 NFS CALIBRATION

This calibration determines the LED current needed to provide an irradiance of 500 mW/cm^2 at the optical port of the equipment under test. Measurements are made using a low duty cycle, ~1%, pattern to minimize self heating. For the example circuit, it's recommended that the LED current remain less than 1.1 A.

1. Determine the active area of the optical port of the equipment to be tested. If not known, use the receiver lens area. Acquire an aperture to match this area.

2. Arrange the NFS and OVC1 to be on-axis at 1.0 cm distance with the aperture as close as possible to D1 of OVC1. Monitor the LED current, I_{LED} (where I_{LED} = delta V_{LEDA}/R1), with an oscilloscope. Set a pulse generator to provide the input signal, Vin, with a Pulse Width = 1.4 to 10 µs and a Duty Cycle = 1%. Check the waveforms at V_{LEDA} and Vo(OVC1) to see that the V_{LEDA} swing is not limited by Vin conditions, that Vo(OVC1) swing is not limited by Vcc and that they are reasonably smooth and not limited by the rise and fall times. (If Vo(OVC1) is supply limited, R1(OVC1) can be reduced, preferred option, or Vcc(OVC1) can be increased.) Allow time to stabilize temperature as LEDs can have significant temperature dependencies.

3. Derive the expected Vo(OVC1) for a 500 mW/cm^2 signal. Use OVC1 to measure irradiance and adjust I_{LED} to reach 500mW/cm^2. If LED current limits are reached, reduce the distance. With the aperture in place, the irradiance is given by

Irradiance = Vo / Area(aperture) x Responsivity(Photodiode) x R1.

4. Arrange OVC2 at a convenient point and use it to observe the optical waveform. Adjust the pulse generator to provide an optical signal pulse width of 2.2 µs and allow the rise and fall times

to be as fast as the LED and circuit can support. Adjust the pulse generator or NFS supply voltage as necessary to maintain a constant amplitude of the LED current waveform and the optical signal. There should be no overshoot in the optical waveform. These are the conditions to produce the maximum optical signal for receiver tests at 115.2 kb/s. For lower data rates, adjust for maximum pulse width while maintaining amplitude.

5. Adjust the pulse generator to provide an optical signal pulse width of 135 ns and allow the rise and fall times to be as fast as the LED and circuit can support. Adjust the pulse generator or NFS supply voltage as necessary to maintain a constant amplitude of the LED current waveform and the optical signal. There should be no overshoot in the optical waveform. These are the conditions to produce the maximum optical signal for receiver tests at data rates of 4 Mb/s, 4PPM. For 576 kb/s and 1.152 Mb/s signals, amplitude and rise and fall times remain the same and the pulse widths are adjusted to 434.0 ns and 217.0 ns, respectively.

2.1.4.2 NFS EXAMPLE IMPLEMENTATION

Table 4: Figure 2.1.4A Example Components

Q1	Si4532DY or NDS 351, Si9936DY
D1	HSDL-4230 or GL551
R1	10 Ohm,± 1%, 0.5 W
R2	50 Ohm, ± 5%, 0.25 W
C1	0.1 µF, ± 20%, 15 V, Z5U or X7R
C2	22 µF, ± 20%, 15 V, Ta or Al
DUT	HSDL-1100 Infrared Transceiver Module
Oscilloscope	HP 54542A
Pulse Generator	HP 8110A

This example circuit with components listed in Table 4 should be able to generate IR pulses with irradiance levels of 500 mW/cm^2 at approximately 1.0 cm, pulse widths > 115 ns and rise and fall times < 40 ns.

For this example, the DUT was an HSDL-1100, which lists on its data sheet an effective detector area of 0.2 cm^2 and a receiver lens radius of 2.87 mm. An aperture with a 5 mm diameter was selected and placed on D1 of OVC1 reducing its effective area to 0.192 cm^2. In addition, R1 of OVC1 was reduced to 50 Ω. The output expected from the modified OVC1 was calculated from

$$
\begin{aligned}
Vo &= \text{Irradiance x Area(Photodiode) x Responsivity (Photodiode) x R1.} \\
&= (500\ \text{mW/cm}^2) \times (0.192\ \text{cm}^2) \times (0.6034\ \text{A/W}) \times (50\ \Omega) \\
&= 2.90\ \text{V.}
\end{aligned}
$$

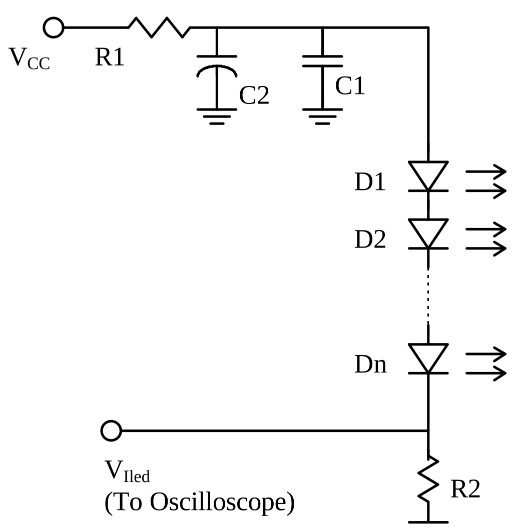
NFS and OVC1 were arranged to be on-axis at 1.0 cm distance with the aperture as close as possible to D1 of OVC1. A pulse generator was set to provide the NFS input signal, Vin, as follows: Low State = 0.0 V, High State = 5.0 V, Pulse Width = 5 µs, Duty Cycle = 1%, tr = 20 ns and tf = 30 ns. NFS Vcc was adjusted until the modified OVC1 yielded the expected result, 2.90 V. LED current pulse amplitude in NFS was noted to be 1050 mA. Waveforms at VLEDA(NFS) and Vo(OVC1) appeared reasonably smooth with rise and fall times less than 20 ns. Vo (OVC1) was checked after several minutes and found to be stable.

OVC2 was set at a convenient point and used to observe the optical waveform. For a data rate of 115.2 kb/s, the pulse generator was adjusted (Low State = 0 V, High State = 5 V, rise time = 2 ns, fall time = 5 ns, Period = 8.68 µs) to provide an optical signal pulse width of 2.2 µs and the NFS yielded the rise and fall times of 25 and 27 ns, respectively. These became the conditions for checking maximum receiver irradiance at a data rate of 115.2 kb/s. The pulse generator should be set to produce a pattern where the overall duty cycle is ≤ 1% to avoid self heating in the LED and voiding the calibration.

For 4 Mb/s, 4PPM, the pulse generator was adjusted (Low State = 0 V, High State = 5 V, rise time = 10 ns, fall time = 30 ns, pulse width = 125 ns) to provide an optical signal pulse width of 135 ns and the NFS continued to yield rise and fall times of 25 and 27 ns, respectively. These became the conditions for checking maximum receiver irradiance at a data rate of 4 Mb/s, 4PPM. The pulse generator should be set to produce a pattern where the overall duty cycle is ≤ 1% to avoid self heating in the LED and voiding the calibration.

2.1.5 IrDA SIMULATED SUN SOURCE: IrDA SSS

Figure 2.1.5A shows a schematic for an infrared source suitable for the IrDA sunlight simulation. (The SSS is used to generate the sunlight ambient condition required for receiver sensitivity or BER measurements in Sections 3.2.1 and 3.2.2. See Physical Layer Specification, Appendix A.) This is a DC IR source and it should have no or very little modulation. Multiple LEDs are used to minimize self-heating. Capacitors, C1 and C2, and resistor, R1, are used to filter the supply voltage. R1 is also used for current limiting. Resistor R2 provides a ground referenced current monitor. The LEDs should be arranged, as close as possible in an array so that their intensity patterns overlap at the desired working distance.



IrDA SSS: IrDA Simulated Sun Source

Figure 2.1.5A

2.1.5.1 IrDA SSS CALIBRATION

1. Arrange the IrDA SSS and OVC1 to be on-axis at a convenient far field distance, approximately 30 to 50 cm. Monitor the LED current, V_{ILED}, with an oscilloscope. Check the waveforms of V_{ILED}(IrDA SSS) and Vo(OVC1) to see that there is no modulation or ripple. (The irradiance measured by OVC1 should have less than 0.3 $\mu W/cm^2$ peak-to-peak modulation.) It may be necessary to shield OVC1 from ambient light to make this measurement. Allow time for temperature to stabilize as LEDs can have significant temperature dependencies.

2. Derive the expected Vo(OVC1) for a 490 $\mu W/cm^2$ signal. Use OVC1 to measure irradiance and adjust I_{LED} to reach the IrDA sunlight requirement. Limit LED current, as appropriate, to constrain self-heating. If necessary, reduce the distance. If available, use a mechanical chopper to permit pulse mode measurements without switching the source and changing its power dissipation.

2.1.5.2 IrDA SSS EXAMPLE IMPLEMENTATION

Table 5: Figure 2.1.5A Example Components

D1 - D7	HSDL-4230 or GL551,
R1	15 Ohm,± 1%, 2 W
R2	1.0 Ohm,± 1%, 0.25 W
C1	0.1 µF, ± 20%, 15 V, Z5U or X7R
C2	22 µF, ± 20%, 15 V, Ta or Al
Vcc	15 to 20 V
Oscilloscope	HP 54542A

This example circuit with components listed in Table 5 should be able to generate the IrDA simulated sunlight irradiance levels of 490 $\mu W/cm^2$ at 30 cm with minimal modulation. The seven LEDs are in rows of 2, 3 and 2 and arranged for maximum packing density.

The output expected from the OVC1 was calculated from

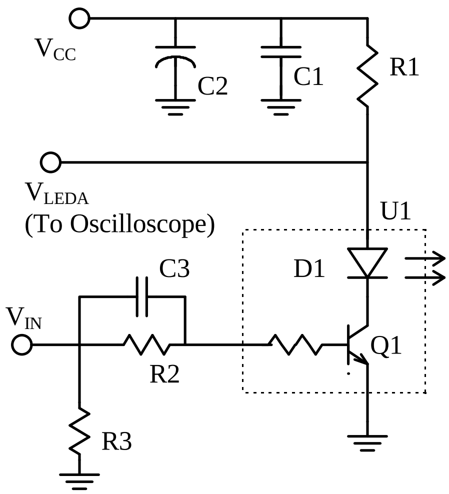
$$
\begin{aligned}
Vo &= \text{Irradiance x Area(Photodiode) x Responsivity(Photodiode) x R1.} \\
&= (490\ \mu W/cm^2) \times (1.0\ cm^2) \times (0.6034\ A/W) \times (500\ \Omega) \\
&= 148\ mV.
\end{aligned}
$$

SSS and OVC1 were arranged to be on-axis at 30 cm distance. The optical signal was mechanically chopped to permit pulse mode measurements. (If a chopper isn't available, the 148 mV could be referenced to a background or ambient measurement.) Signals V_{ILED} and V_{CC} of SSS and Vo(OVC1) were monitored. SSS V_{CC} was adjusted until Vo(OVC1) yielded the expected result, 148 mV. LED current in SSS was noted to be 110 mA. Waveforms at V_{ILED}(SSS) and Vo(OVC1) appeared DC with average noise amplitude less than 0.36 mV at V_{ILED}(SSS) and less than 0.33 mV at Vo(OVC1). In both cases the noise appeared dominated by RFI pickup in the test fixtures. Vo (OVC1) was checked after several minutes and found to be stable.

2.1.6 IrDA FLUORESCENT LIGHTING INTERFERENCE SOURCE: IrDA SFS

Figure 2.1.6A shows a schematic for an infrared source suitable for an IrDA Simulated Fluorescent Lighting Source. (The SFS is used to generate the fluorescent lighting ambient condition required for receiver sensitivity or BER measurements in Sections 3.2.1 and 3.2.2. See

Physical Layer Specification, Appendix A.) This is essentially a copy of the Far Field Source, FFS-B (See Section 2.1.3.), but calibrated for the IrDA fluorescent lighting interference level. Separate sources are required as they are used together.



IrDA SFS: IrDA Simulated Fluorescent Source

Figure 2.1.6A

2.1.6.1 IrDA SFS CALIBRATION

See Section 2.1.3.1 FFS Calibration for procedure . For the lower irradiance level, modify the FFS-B procedure for lower LED currents in Step 2 (Include I_{LED} = 2 mA and 5 mA; 30 mA and 100 mA measurements can be skipped.) and for a longer working distance of 50 to 100 cm in Step 3 (Either extend the distance in Step 3 to a longer distance or maintain Step 3 and depend upon a inverse square roll-off beyond 30 cm.). The modulation for this signal is a square wave with a 20 to 200 kHz frequency range. Use pulse generator settings that yield rise and fall times as fast as the LED and circuit can support. Calibration is recommended with 200 kHz bursts with gaps sufficient to reach an overall 1% duty cycle. While this is not expected to be a factor in use as the LED current is expected to be low, it will be a factor in the calibration due to the measurements made at 200 mA and 500 mA.

2.1.6.2 IrDA SFS EXAMPLE IMPLEMENTATION

Table 6: Figure 2.1.6A Example Components

U1	HSDL-1100 or GL1F20, HRM200S, TFDS6000, MiniSIR
R1	10 Ohm,± 1%, 0.5 W
R2	560 Ohm, ± 5%, 0.25 W
R3	50 Ohm, ± 5%, 0.25 W
C1	0.1 µF, ± 20%, 15 V, Z5U or X7R
C2	22 µF, ± 20%, 15 V, Ta or Al
C3	220 pF, ± 10%, X7R
Oscilloscope	HP 54542A
Pulse Generator	HP 8110A

2.1.7 IrDA INCANDESCENT LIGHTING INTERFERENCE SOURCE

A 100 watt incandescent lamp is recommended as the light source for the IrDA Incandescent Lighting Ambient. (This source is used to generate the incandescent lighting ambient condition required for receiver sensitivity or BER measurements in Sections 3.2.1 and 3.2.2. See Physical Layer Specification, Appendix A.) This should be a general service, tungsten-filament, gas-filled, inside-frosted lamp. Use of a reflector is recommended to increase the working distance. A 40 to 50 cm distance from the DUT should be possible.

A direct measurement can be made with a photometer calibrated in lux to determine the distance from the lamp for a 1000 lux level. It's advised that the mounting orientation of the lamp be the same for calibration as for use, as different orientations can result in different lamp filament temperatures and, consequently, different light levels or power spectrums. Allow temperature to stabilize before calibration.

2.1.8 EXAMPLE IMPLEMENTATIONS COMPONENTS

COMPONENT	TYPE	TEST CIRCUIT	SOURCE
UDT 10D	PIN Photodiode	OVC1, D1	UDT Sensors, Inc 12525 Chadron Ave. Hawthorne, CA 90250 Tel: 310-978-0516 Fax: 310-644-1727
BPV23NF TSHA550 TFDS6000	PIN Photodiode IR LED IrDA Transceiver	OVC2, D1 FFS-A, D1 alternate FFS-B, U1 alternate	TEMIC Tel: 408-988-8000 Fax: 408-567-8959 www.temic.com
DET200	PIN Photodiode	OVC2, D1 alternate	Thorlabs, Inc Tel: 973-579-7227 Fax: 973-383-8406 www.thorlabs.com
HSDL-4220 HSDL-1100 HSDL-4230	IR LED IrDA Transceiver IR LED	FFS-A, D1 FFS-B, U1 NFS, D1 & SSS, D1-Dn	Hewlett-Packard Tel: 800-235-0312 or 408-654-8675 www.hp.com/go/ir
GL1F20 GL551	IrDA Transmitter IR LED	FFS-B, U1 alternate FFS-A, D1 alternate NFS, D1 alternate SSS, D1-Dn alternate	Sharp Tel: 800-642-0261 Fax: 800-833-9437 www.sharpmeg.com www.sharp.co.jp
HRM200S	IrDA Transceiver	FFS-B, U1 alternate	I I Stanley Los Angeles Sales Office Tel: 800-LED-LCD1 or 714-220-0777 Fax: 714-222/0555
MiniSIR	IrDA Transceiver	FFS-B, U1 alternate	Novalog Tel: 714-429-1122 Fax: 714-549-5711 www.novalog.com
Si4532DY NDS351 Si9936DY	MOSFET MOSFET MOSFET	NFS, Q1 NFS, Q1 alternate NFS, Q1 alternate	Siliconix Tel: 800-554-5565 Fax: 408-970-3950

2.2 TEST EQUIPMENT

Test equipment needed to implement and use the circuits in Section 2.1 include an oscilloscope, a pulse generator, power supplies, a digital multimeter and a photometer as well as means to measure distances and angles. A fast IR source is useful for calibration of OVC2, but not necessary. Other useful items include an IrDA protocol analyzer or IrDA primary, IR viewers (most video cameras will image IR in the wavelength of interest), optical rails and fixtures, including rotating stages to facilitate alignment and measurements of angles and spacing. The measurement methods of Section 3 may require the addition of a frequency counter to achieve the resolution needed by the tight signaling rate tolerances for rates above 115.2 kb/s. The critical items are discussed below.

2.2.1 OSCILLOSCOPE

This is the primary measurement instrument. Almost all signals of interest are pulses which are converted to voltage waveforms and measured via the available oscilloscope functions. The measurements recommended in Sections 2.1 and 3 require the following characteristics.

> 2 Channels
> Input Voltage Range: 1mV/Div to 1V/Div
> Bandwidth ≥ 100 MHz to support measurements of rise and fall time < 8 ns
> Time Interval Accuracy ≤ 1ns to support measurements of jitter < 5 ns
> Signal averaging, pulse parameter measurements (tr, tf, tpw, Vamptd, Vtop and Vmax) and statistical functions are useful but not necessary.

In the example implementations of Section 2.1 a Hewlett Packard HP54542A Digitizing Oscilloscope was used and is considered sufficient but not necessary.

2.2.2 PROGRAMMABLE PULSE GENERATOR

Rigorous receiver BER tests require worst case data patterns with worst case pulse shapes. To achieve the worst case data patterns, a programmable pulse generator can be set to transmit IrDA frames or IrDA equipment can be used to drive the pulse generator. To achieve worst case pulse characteristics of pulse width, jitter and rise and fall time, the capabilities of a pulse generator are usually required.

In the example implementations of Section 2.1 a Hewlett Packard HP8110A Pulse Generator was used and is considered sufficient but not necessary.

2.2.3 FAST IR SOURCE

A fast switching IR source is useful, but not necessary, for calibration of OVC2. In the example implementation of Section 2.1.2.2 a Broadband Communications Products (http://www.iu.net/bcp/) BCP Model 400 Laser Transmitter was used.

2.3 TEST ENVIRONMENT

For these guidelines, optical measurements are made at short distances to get strong signals. Amplitude measurements to yield intensity information, however, must be in the far field in order to extrapolate results to 1 meter links where signal levels are too low for simple measurements. Measurements are generally in pulse mode which facilitates canceling out ambient interference. Some digitizing oscilloscopes offer measurement and statistical functions which significantly simplify effort and improve results.

Although the procedures should accommodate normal room lighting, results improve with low levels of ambient lighting. Setups should be arranged to minimize ambient light and reflections from test sources. Black or non-reflective surfaces are recommended. Rough or matte surfaces are preferred as scattering can be more effective than absorption. Strategic use of black cloth, baffles and/or apertures is helpful. Elevating the link 25% to 30% of the link length from the work surface should help reduce reflections from the brightest region of the intensity pattern for 15 degree radiation cones.

An even and stable ambient temperature is important. Although, the procedures minimize self-heating, there are no provisions for temperature compensation and LEDs have significant temperature dependencies. Strong interference sources should be avoided, especially IR and conducted RFI.

2.4 TEST FRAMES

IrDA provides, but does not require, the availability of test frames. Where available, test frames especially enhance the ability to measure transmitter data rate, transmitter jitter and receiver BER. Frame description is available in IrLAP. Fortunately, much can be accomplished with the required command and response frames - see Section 2.4.3.

Test frames utilize IrLAP frame structure illustrated below.

BOF	BOF	ADDRESS	DATA FIELD	CRC16	EOF

Data rates up to 115.2 kb/s

STA	STA	ADDRESS	DATA FIELD	CRC16	STO

Data rates from 576 kb/s to 1.152 Mb/s

Preamble	STA	ADDRESS	DATA FIELD	CRC32	STO

Data rate of 4.0 Mb/s

2.4.1 TEST FRAME FOR JITTER MEASUREMENT (FRAME J)

Test frames, Frame J, which would provide a good pattern for measuring jitter were developed. These frames for jitter measurement include the following DATA FIELD of 8 bytes repeated as needed to fill the data field with the specified number of bytes.

(1) DATA FIELD for 2400 b/s to 1.152 Mb/s:

X'7F', X'5A', X'0F', X'33', X'77', X'40', X'00', X'BA'

(2) DATA FIELD for 4 Mb/s:

X'70', X'0C', X'12', X'58', X'9A', X'B4', X'EF', X'33'

2.4.2 TEST FRAME SEQUENCE FOR BER MEASUREMENT (SEQUENCE B)

Test frame sequences for Bit Error Rate, BER, measurement are constructed with 15152 frames where each frame contains 64 bytes of random data in the DATA FIELD. If 15152 test frames (=1Mbits/66bytes) are received correctly, the BER is less than 10^{-7}.

2.4.3 TESTS WITH NORMAL COMMAND AND RESPONSE SEQUENCES

Where test frames are not available, an XID Command Frame can be generated by the test source to solicit a somewhat predictable response, XID Response Frame, from the equipment under test

(DUT). This frame is normally used for device discovery which occurs at 9.6 kb/s and is only available at that data rate. Below is a XID Command with a recommended address and the expected XID Response. The device address in the command frame, X'7B', X'7F', X'5F', X'77', is repeated in the response frame and provides a usable data pattern for measuring pulse characteristics.

XID Command: X'C0', X'C0', X'FF', X'3F', X'01', X'7B', X'7F', X'5F', X'77', X'FF', X'FF', X'FF', X'FF',X'00', X'00', X'00', X'00', X'65', X'99', X'C1'

XID Response: X'C0', X'C0', X'FE', X'BF', X'01', X'ii', X'jj', X'kk', X'll', X'7B', X'7F', X'5F', X'77', X'mm', ... X'nn', X'pp', X'qq', X'C1'

The bytes X'ii', X'jj', X'kk', X'll' contain the device address of the DUT which while not predictable will not change once the test link is established. Similarly, the response contains an unpredictable count of bytes, X'mm', ... X'nn', which contain device information and will not change once the test link is established. Finally, the bytes X'pp', X'qq' contain the CRC which, again, while not predictable will not change once the test link is established. Once the test link is established the XID Command can be repeated with, now, consistent results.

2.4.4 TESTS AT DATA RATES ≠ 9.6 kb/s

A shift to data rates other than 9.6 kb/s requires establishing a connection and a negotiation to the desired rate. This requires capturing, from the XID Response frame, the device address of the equipment under test, which is unpredictable, and repeating it in later command frames. While this is beyond the scope of the simple test sources described in Section 2.1, a protocol analyzer or another IrDA primary could be substituted to handle the negotiation. This frame sequence is given below.

Node	Frame
Test Source	XID Command
DUT	XID Response
Test Source	End XID
Test Source	SNRM Command
DUT	UA Response
Test Source	RR
DUT	RR
Test Source	Test Command
DUT	Test Response

After the UA Response, the Test Source and DUT shift to the negotiated data rate and will continue to trade RR frames at that rate. At this point the calibrated test sources of Section 2.1 can be re-introduced. Where test frames are not available, it may be necessary to find some other means to achieve larger frames than the RR frame.

3. MEASUREMENT METHODS

This section provides recommendations for measurements of parameters in the following table. The Infrared Data Association Serial Infrared Physical Layer Link Specification provides descriptions and definitions for the various parameters and in Appendix A describes test methods. Section 2.1 of this document describes test circuits and their calibration.

PARAMETER	Minimum limit	Maximum limit
ACTIVE OUTPUT		
Peak Wavelength, μm	Min	Max
Intensity In Angular Range, mW/sr	Min	Max
Half-Angle	Min	Max
Signaling Rate	Min	Max
Rise Time	Min	Max
Fall Time	Min	Max
Pulse Duration	Min	Max
Over Shoot		Max
Edge Jitter	Min	Max
ACTIVE INPUT		
Irradiance In Angular Range, mW/sr	Min	Max
Half-Angle	Min	Max
Latency		Max

In general, irradiance measurements are recommended at short distances to get strong signals. Irradiance amplitude measurements should be in the far field to yield accurate intensity results and in order to extrapolate results to one meter links where signal levels are too low for simple measurements. Measurements are generally recommended in pulse mode which facilitates canceling out ambient interference. Some digitizing oscilloscopes offer measurement and statistical functions which significantly simplify effort and improve results.

3.1 ACTIVE OUTPUT

3.1.1 Peak Wavelength

The peak wavelength may be measured with commercially available optical spectrum analyzers. Refer to the Physical Layer Specification Active Output Interface Definitions.

Due to the cost and narrow purpose of this equipment, deferring to component data sheets will be considered sufficient. Although peak wavelength can change with temperature (~ 0.25 nm/°C) and be affected by optical filters, the rationale is the expectation that most receiver implementations have sensitivity ranges wider than 850 nm to 900nm and that there is little loss of sensitivity for small transgressions of this requirement.

3.1.2 Intensity and Angle

The output power (intensity) may be measured with the optical power to voltage converter (OVC1) of Figure 2.2.1A. Refer to the Physical Layer Specification: Active Output Interface and Optical

Angle Definitions, Media Interface Specifications and Appendix A for definition of terms and parametric limits. Intensity can be affected by frame length and it is recommended that intensity measurements be made with long as well as short frames.

1. Set-up the equipment under test, DUT, in normal orientation and center OVC1 on the optical axis of the DUT directly facing the DUT, such that the optical axes of the DUT and OVC1 are coincident.

2. Set the equipment under test to transmit at 9.6 kb/s under internal control or solicit a response via external means. See Section 2.4. Observe the pulse amplitude to check that the amplitude is not limited by the rise time of the signal. For accurate amplitude measurements, the signal, Vo, must have a rise time less than the pulse width of the optical signal and magnitude well above the sensitivity limits of the oscilloscope.

3. Measure irradiance (See Section 2.1.1.) and convert to intensity, on-axis, at 15cm. The expression for irradiance is

Irradiance = Vo / Area(Photodiode) x Responsivity(Photodiode) x R1.

The expression for intensity is

Intensity = Irradiance x $(\text{Distance})^2$
= Vo x $(\text{Distance})^2$ / Area(Photodiode) x Responsivity(Photodiode) x R1

4. Repeat at 20 and 30 cm to check that the irradiance result is rolling off as the inverse square of the distance while the intensity result remains relatively constant for distances larger than 20 cm. If not check alignment or for reflections or try a larger distance.

5. At 0 degrees and ≥ 20 cm, measure the irradiance and check for conformance with Minimum and Maximum Intensity In Angular Range specifications.

6. At 0 degrees and ≥ 20 cm, increase the angle (Rotate the DUT clockwise relative to the source; maintain constant distance between source and DUT optical port.) in the horizontal plane until the Minimum Intensity In Angular Range specification is reached. Record this as a positive angle for the Half-Angle of this orientation. Repeat with a counter-clockwise rotation for negative angles. Check the Half-Angles for conformance with Half-Angle minimum and maximum specifications. The Maximum Intensity In Angular Range specification should not be exceeded at any point.

7. Repeat steps 5 and 6 in the vertical plane and other planes as appropriate.

8. Repeat for other data rates of interest. See Section 2.4. At data rates above 115.2 kb/s, the converter circuit, OVC1, may not have sufficient bandwidth to preserve the signal. If so, at some data rate within the bandwidth of OVC1, place OVC2 in the near field for a strong signal, calibrate it for amplitude measurements to OVC1 and continue.

3.1.3 Pulse Parameters

The output power (intensity) pulse characteristics may be measured with the wideband power to voltage converter (OVC2) of Figure 2.1.2A. Refer to the Physical Layer Specification Active Output Interface Definitions, Media Interface Specifications and Appendix A for definition of terms and parametric limits. Pulse duration, signal rate and edge jitter can be affected by the length of time between pulses and, consequently, when measuring these parameters, it is important to take readings at several points in a data pattern including those with minimum and maximum allowable time between pulses.

1. Set the equipment under test to transmit at 9.6 kb/s under internal control or solicit a response via external means. See Section 2.4.

2. Set-up the equipment under test in its normal orientation, place the OVC2 to be approximately 5 cm distant from the optical port and on-axis and align for a strong signal.

3. Measure Rise Time, Fall Time and Pulse Duration. Pulse width results can be taken directly from the oscilloscope. Rise and fall times may need adjustment depending on the response time of OVC2 (See section 2.1.2). Check for conformance with the respective Minimum and Maximum specifications.

4. Measure Optical Over Overshoot. The Vamptd or Vtop oscilloscope functions, where available, can be used to define the 100% level. If not available, refer to Appendix A of the Infrared Data Association Serial Infrared Physical Layer Link Specification for definition of the 100% level. Then oscilloscope function, Vmax, where available, or visual observation can be used to note transitions above this 100% level. Check for conformance with the respective Maximum specifications.

5. Measure Signaling Rate. Check for conformance with the respective Minimum and Maximum specifications. This measurement is to stay within a byte for data rates ≤ 115.2 kb/s. An oscilloscope may not provide sufficient resolution for the data rates above 115.2 kb/s and a frequency counter may be needed.

6. Measure Edge Jitter. Check for conformance with the respective Minimum and Maximum specifications. Note that there are different jitter definitions for the various data rates. This measurement is to stay within a byte for data rates ≤ 115.2 kb/s.

7. Repeat steps 3 through 7 for other data rates of interest. See Section 2.4.

3.2 ACTIVE INPUT MEASUREMENTS

3.2.1 Minimum Irradiance

The input sensitivity may be measured with one of the far-field test sources of Figure 2.1.3A. Refer to the Physical Layer Specification: Active Input Interface Definitions, Optical Angle Definitions, Media Interface Specifications and Appendix A for definition of terms, interference conditions and parametric limits.

1. Set-up the equipment under test, DUT, in its normal orientation and place the far-field test source at the distance and angle from the optical port for which it is calibrated to provide the minimum specified irradiance as determined in Section 2.1.3.1 and adjust the optical signal for minimum pulse width and maximum rise and fall times. The same minimum pulse width and maximum rise and fall times cover all data rates less than or equal to 115.2 kb/s.

2. Activate the test source to provide test patterns at 9.6 kb/s (see Section 2.4) and observe the DUT within +/- 15 degrees for conformance to the maximum Bit Error Ratio, BER, specification. Since the BER test can be long, it's advisable to lower the irradiance to raise the BER and scan within +/- 15 degrees to find the angle of worst case sensitivity. Similarly, adjust the test source to find the worst case for clock frequency and jitter (the worst case for jitter is often found to occur in combination with minimum and/or maximum spacing between pulses) and activate the various ambient interference conditions to see which combination provides the most severe degradation in BER and only run the actual test at the worst case combination of interference, clock frequency, jitter and angle. Refer to Appendix A, IrDA SIR Physical Layer Link Specification for light and EMI ambient requirements; descriptions of IR ambient sources are contained in Section 2.1.5 IrDA Simulated Sun Source, Section 2.1.6 IrDA Fluorescent Lighting Interference Source and Section 2.1.7 IrDA Incandescent Lighting Interference Source. An irradiance reduction of approximately 48% should raise a BER of 10^{-8} to 10^{-3}. If possible, test frames longer than 10 ms with random data patterns should be used, both, to reduce the test time and to check for frame length and pattern dependencies.

3. Repeat step 2 for other data rates; the worst case angle should remain constant. For data rates less than or equal to 115.2 kb/s, the minimum irradiance increases. Above 115.2 kb/s, the tolerance for clock frequency and jitter of the test source tightens and at the 4.0 Mb/s data rate, clock skew between test source and DUT can have significant effect. The worst case combination of interference, clock frequency, jitter and angle for BER from Step 2 should be re-examined.

4. Repeat in the vertical plane and other planes as appropriate.

3.2.2 Maximum Irradiance

The maximum input irradiance may be measured with the near-field test source of Figure 2.1.4A. Refer to the Physical Layer Specification: Active Input Interface Definitions, Optical Angle Definitions, Media Interface Specifications and Appendix A for definition of terms, and parametric limits.

1. Set-up the equipment under test, DUT, in its normal orientation and place the near-field test source at the distance and angle from the optical port for which it is calibrated to provide the maximum specified irradiance and adjust the optical signal for maximum pulse width and rise and fall times as determined in Section 2.1.4.1.

2. Activate the test source to provide test patterns at 9.6 kb/s, adjust the test source to find the worst case for clock frequency and jitter, activate the various ambient interference conditions to see which combination provides the most severe degradation in BER and only run the actual test at the worst case combination of interference, clock frequency and jitter (the worst case for jitter is often found to occur in combination with minimum and/or maximum spacing between pulses). Refer to Appendix A, IrDA SIR Physical Layer Link Specification for light and EMI ambient requirements; descriptions of IR ambient sources are contained in Section 2.1.5 IrDA Simulated Sun Source, Section 2.1.6 IrDA Fluorescent Lighting Interference Source and Section 2.1.7 IrDA Incandescent Lighting Interference Source. Observe the DUT for conformance to the maximum Bit Error Ratio, BER, specification. If possible, use short test frames to avoid minimize self-heating of the test source. Reduce the irradiance to check that lower levels are not problematic.

3. Repeat for other data rates of interest. Above 115.2 kb/s, the tolerance for clock frequency and jitter of the test source tightens and at the 4.0 Mb/s data rate, clock skew between test source and DUT can have significant effect. The worst case combination of interference, clock frequency, jitter and angle for BER from Step 2 should be re-examined.

3.2.3 Receiver Latency

1. Set-up the equipment under test in its normal orientation and setup the far-field test source to repeat the worst case minimum irradiance condition determined in Section 3.2.1. Activate the test source to provide a test pattern, establish a link so that the equipment under test is alternately transmitting receiving and observe the equipment under test for correct operation. If a worst case angle for receiver sensitivity is known, the test can be reduced to just that angle. Adjust the test source so that it follows a transmission by the equipment under test with a transmission at the latency time supported by the equipment under test. Observe for correct operation.

2. Repeat for other data rates. For data rates greater than 115.2 kb/s, the minimum irradiance increases.