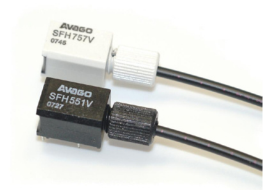
General Information for Avago SFH series Plastic Fiber Components (PFC)

Application Note 5342



Introduction

Optical communications offer important advantages over electrical transmission links. The following characteristics make the technology particularly attractive for a wide range of applications:

- Insensitivity to electromagnetic interference
- Voltage decoupling between emitter and detector
- Security against tapping
- No sparking at fiber ends or breaks
- No ground loops

Yet despite the many potential application areas arising from these advantages, the use of optical glass fiber is restricted due to its relatively high cost. Where demands are for medium bit rates and distances, by far the more cost effective solution today is offered by Plastic Optical Fiber (POF) in combination with Avago Plastic Fiber Components (PFC) emitters and detectors. These low cost components permit the use of plastic fibers even in the most cost-sensitive applications, such as:

- Optical networks (industrial and medical)
- Motor controls, links between power and control units
- Replacement of connections with copper wire and optocoupler (within cabinets)
- High voltage optocouplers
- Building information and control systems
- Light barriers
- Household electronics

SFH Series Components

Data transmission at 650 nm is very popular because of cost-effective component availability. To meet the market demand, Avago offers specially designed transmitter and receivers for 650 nm transmission that feature a very easy fiber coupling mechanism. The cut fiber only has to be inserted into the plastic package, which has an aperture for standard 2.2 mm fibers. No connector-mounting is necessary. The Avago solution greatly reduces assembly costs.

SFH Series Components

Product	Ordering Information	Feature	Max. Data Rate	Wavelength	Direct Fiber Connector Housing
SFH757	SP000063871	Transmitter Diode	100 MBd	650 nm	No
SFH757V	SP000063858	Transmitter Diode	100 MBd	650 nm	Yes
SFH250	SP000063866	Receiver (analogue out), Photodiode	100 MBd	650 nm	No
SFH250V	SP000063852	Receiver (analogue out), Photodiode	100 MBd	650 nm	Yes
SFH551/1-1	SP000063860	Receiver (digital out), Photodiode + TIA*	5 MBd	650 nm	No
SFH551/1-1V	SP000063855	Receiver (digital out), Photodiode + TIA*	5 MBd	650 nm	Yes

* Includes an integrated transimpedance amplifier (TIA) and Schmitt trigger

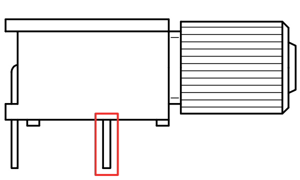
Optical-Mechanical Design

A particular advantage of Avago´s SFH series is the housing aperture into which a standard plastic fiber (external diameter of 2.2 mm) may be introduced without having to remove the cladding. This has the additional benefit of automatically aligning the fiber onto the chip. Therefore the SFH series components are optimized for easy coupling. No fiber stripping is required; just insert the cut fiber into the selected SFH component.

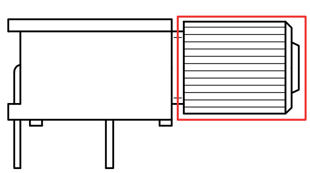
There are two versions of each SFH component available – with and without a "Direct Fiber Connector Housing". The housing allows easy coupling of an unconnectorized 2.2 mm polymer optical fiber by means of an axial locking screw. With the recommended locking torque of 15 cNm and the use of a suitable fiber, a pullout force of approximately 50 N can be reached. This force should be sufficient to support most applications, assuming the components are properly handled. The option "Plastic Direct Fiber Connector housing (V-housing)" has numerous advantages:

- The cladding need not be removed
- A connector on the fiber is not necessary
- The plastic fiber is connected by a simple turn of the locking screw
- The component is suitable for automatic board assembly
- The fiber itself does not turn when the cap is screwed tight
- Every plastic fiber with an external diameter of 2.2 mm and an internal diameter of 1 mm can be used
- Small housing dimensions
- The housing protects photodetectors from external light sources

The emitter is mounted in a white housing and the detectors in a black one. Two mounting pins are provided on the housing for firm attachment to boards.



Package V-housing mounting pins



Package V-housing axial locking screw

Fiber

Transmission suitable optical fibers, often called cables, are needed for information transport in the form of light pulses. Avago offers plastic optical fiber (POF) for 650 nm applications. Typical fiber attenuation is approximately 0.22 dB/m at 25° C. For power budget calculations, fiber properties are an important factor. For example, high temperature and humidity increase fiber aging factors. Possible coupling losses are also an important factor for dimensioning the optical transmission link. All these factors, and even more, make proper fiber selection a critical factor in designing a safe and reliable transmission link. Avago offers all the necessary fiber link components for a reliable and cost-effective data transmission system.

The HFBR-C/R/EXXYYYZ series of Avago´s plastic fiber optic cables are constructed of a single step-index fiber sheathed in a black polyethylene jacket. The duplex fiber consists of two simplex fibers joined with a zipcord web. Standard (Type="R") and Extra Low Loss (Type="E") cables comply with UL VW-1 flame retardant specification (UL file # E89328) except for Commercial (Type="C") cables are available in unconnectored or connectored options. Please refer to the data sheet and the ordering guide for part information.

Avago offers 1 mm diameter Plastic Optical Fiber (POF) in 3 grades:

- Commercial POF with 0.22dB/m typical attenuation (0°C to 70°C)
- Standard POF with 0.22 dB/m typical attenuation (-40°C to 85°C)
- High performance Extra Low Loss POF with 0.19 dB/m typical attenuation (-40°C to 85°C)

Electrical and Optical Characteristics

Avago´s SFH series were designed for an operation temperature range from -40° C to +85° C.

Characteristics of the Emitter Diode

The SFH757 is a low-cost transmitter diode for optical data transmission with polymer optical fiber. Its InGaAlP LED chip is designed to emit light at 650 nm. The robust SFH757 can be used for speeds up to 100 MBd and complements the Avago SFH250 photodiode receiver and SFH551/1-1 integrated photodetector receiver.

For the electrical and optical characteristics of Avago's SFH757 transmitter please refer to the data sheet. Additional information is also available in Application Note 5341 "Driver and Receiver Circuits for Avago SFH series Plastic Fiber Components (PFC)".

Characteristics of the Photodetectors

The SFH250 is a low-cost 650 nm receiver for optical data transmission with polymer optical fiber. This Si-pin-photodiode works fine with the AVAGO transmitter SFH757. According to the intensity of the incident light, the SFH250 generates an analog photocurrent. In typical applications the SFH250 is operated with reverse bias and is installed in series with a resistor, where the voltage tapping is taken. By increasing the reverse voltage, switching times decrease, and the SFH250 can be used for transmission speeds up to 100MBd.

The SFH551/1-1 receiver is a transimpedance amplifier with an integrated photodiode and TTL open-collector output stage. The active area of this detector combined with the molded microlens gives an efficient coupling from the end of the polymer optical fiber. This receiver enables data rates up to 5 MBd and works with the Avago SFH757 transmitter diode.

For the electrical and optical Characteristics of Avago´s SFH250 and SFH551/1 1 receivers, refer to the data sheets. Additional information is also available in Application Note 5341 "Driver and Receiver Circuits for Avago SFH series Plastic Fiber Components (PFC)".

The detector is placed at the other end of the link and converts the optical signal back to an electrical signal. This receiver must be able to accept highly attenuated power down to nanowatt levels. Subsequent stages of the receiver amplify and reshape the electrical signal back into its original shape.

Principle of the Digital Receiver

An integrated optical receiver in an optical transmission system has the following parts:

Using a built-in lens, the light leaving the plastic fiber is focused onto the photodiode of the IC. The photodiode integrated in the device converts the received light into photocurrent.

The preamplifier converts the photocurrent into voltage. Usually, a transimpedance amplifier is applied. A resistor in the amplifiers feedback loop determines the current to voltage conversion. To avoid pulse disturbance, the amplifier must have a linear performance over the entire power range of the received light.

The comparator following the signal path converts the signal to a logic signal. Here, the preamplifier's output voltage is compared to a reference voltage and the decision to set the output high or low is made. As the signal may be noisy, a (small) undefined voltage range occurs around the reference level. Typical input signals go through this range very fast and no degradation of the output signal can be observed. However, if the signal slowly increases towards the decision threshold, the output can run into undefined states. Thus, noise peaks may occur with amplitudes reaching the switching threshold of the following stages.

To remove this effect, the SFH551/1-1 (Figure 1) is equipped with a Schmitt trigger which works with different thresholds. If the output is 'off' a high signal level is required for switching to the on-state, whereas a lower level has to be reached to switch back to the off-state. Therefore, the probability is greatly reduced that small noise signals will cause unwanted switching errors.

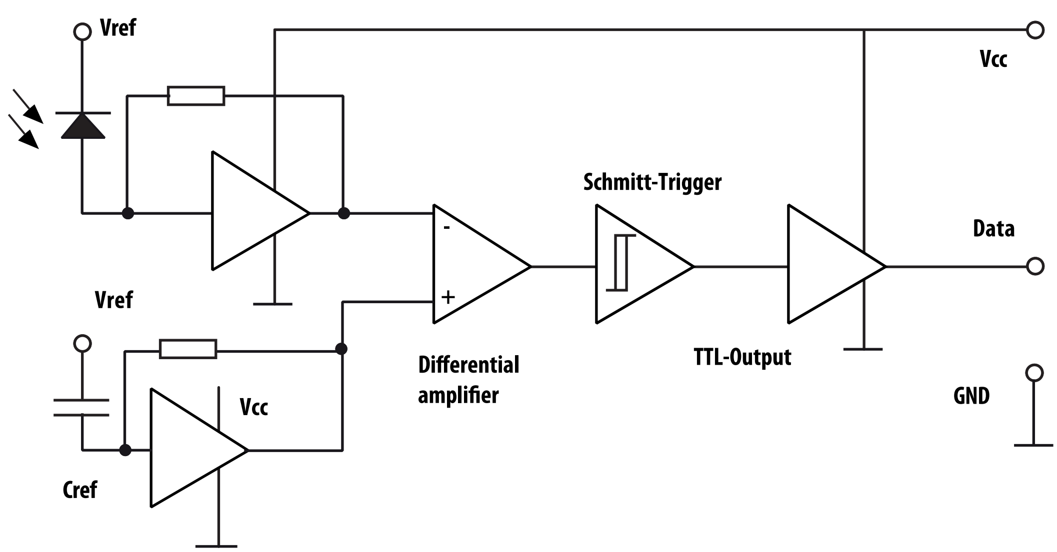


Figure 1. Typical circuitry of the SFH551/1-1 with built-in Schmitt Trigger

DC-Coupled Receiver Operation with a Fixed Threshold

The form of the signal that is internally delivered from the transimpedance amplifier to the decision circuit considerably determines the performance of the receiver. This form itself is determined by the optical receiver signal and its processing in the preamplifier.

The received optical signal is determined by the following items:

- Bias light caused by scattering or residual emission of the transmitter in the switched off state
- Rise and fall times that depend on the transmitter's control signal, the transmitter's speed and possibly effects from the transmission link
- Pulse amplitude that depends on emission power and the loss of the optical transmission link.

The preamplifier integrated in the SFH551/1-1 is designed for wide bandwidth. Consequently, large disturbances do not occur within its linear working range.

Fixed Decision Receiver Threshold Cross

If the input signal is too small and does not reach the decision threshold, the decision circuit does not change its output state. A short peak exceeding the threshold results in a correspondingly short output pulse.

If the level of the input signal is very high, this results in an early transition to the on-state and a delayed transition to the off-state. Consequently, the delay of the electrical signal caused by the falling edge of the optical signal is longer than the delay of the rising edge (optical signal).

If the transmitter signal is DC-biased (at logical zero) or additional light hits the receiver, the noise signal is shifted to the decision threshold. Without the Schmitt trigger unwanted pulses may occur at the output. The SFH551/1-1 with its built-in Schmitt trigger eliminates this problem.

Highly biased signals (at logical zero) cause a permanent switch to the on state and therefore prohibit data transmission. For a full optical receiver performance evaluation, he effects described above demonstrate that the level and form of the optical input signal must be taken into account.

Receiver Operating Limits

Dynamic range:

Dynamic range is the difference between the smallest and highest signal level for which perfect operation is assured. It is an important figure for evaluating an optical receiver's performance.

SFH551/1-1: minimal light power

A typical behavior of the SFH551/1-1 is increased sensitivity with increasing temperature. Therefore the threshold level of the SFH551/1-1 at low operating temperaturs is at a higher optical peak power limit (20 µW; -17 dBm) compared with operation at TA=25° C.

SFH551/1-1: maximal light power

A typical behavior of SFH551/1-1 is increased sensitivity with increasing temperature. The maximum light power of this receiver, also called "overdrive limit" is typically measured as temperature mean value. The overdrive limit at high operating temperature is 252 µW (-6 dBm) and at TA=25° C 1m W (0dBm).

Please note that the actual maximum light power limit depends on the application and the actual data rate; therefore the pulse width distortion must be taken into account.

Application Hints

SFH551/1-1 power supply

For printed circuit board mounting it must be taken into account that the SFH551/1-1 is a fast electronic circuit. A blocking capacitor (100 nF) is recommended for the SFH551/1-1. The receiver can be operated at Vcc=5.0V. A noisy power supply can be connected via a resistor to build a low-pass filter together with the capacitor. Despite this filter, almost the full output level can be reached, if the pull-up resistor is connected to Vcc.

SFH551/1-1 pull-up resistor selection

To keep the current consumption low, a high value within the possible range is usually chosen. For very fast systems it might be important to work with the minimal value. The calculation of the minimal value, however, should not be performed with the maximal output current. For the SFH551/1-1 a pull-up resistor of at least 330 Ω is recommended.

SFH551/1-1 signal delay

The design of the receiver has resulted in a small delay time increase. This becomes clear if the pulse form of the SFH551/1-1 is taken into account. The rising edge is fast; the delay time increases only for a very small light power.

For more details about signal delay times, please read the SFH551/1-1 data sheet and application note AN5341.

POF cable treatment

Due to the thick diameter of POF, it is easier to handle than glass fiber. Thus for very short distances, where plenty of allowance has been made for attenuation, it is possible to cleave the fiber using a sharp-edged blade. For longer stretches wet polishing the fiber end with 600 grain sandpaper yields greatly improved results.

Cut fiber connection to SFH Components

When current flows in the forward direction, the SFH757 emitter diode emits optical radiation. The housing is designed to maximally couple the light output into the fiber. The component is intended for use with plastic optical fiber, and thus the data regarding optical coupling into and out of the fiber refers to standard plastic fiber with a core diameter of 980 µm, and a cladding of 20 µm. With a PE protection sheath, the POF cable has a total diameter of 2.2 mm. A numerical aperture (NA) of 0.47 is typical.

Detector

When dimensioning the detector it is necessary to establish the dynamic range, that is the relation between the minimum current required and the maximum permissible current.

System planning

The basic principle for a stable fiber optical transmission is simple: the transmitted optical signal must reach the optical receiver with a sufficient amplitude (optical power) and signal quality. However, determining the valid limits of the necessary power budget calculation can be a challenge.

The received optical power should be at least double (+3 dB) the receiver´s limit sensitivity to ensure that systemic noise and irregularities do not cause sporadic transmission errors. An application dependent system reserve has also to be taken into account.

SFH-series components are designed for transmissions at 650 nm; therefore a cost effective plastic optical fiber (POF) with a standard core diameter of 1mm is recommended.

All electrical and optical parameter in the SFH757, SFH250 and SFH551/1-1 data sheets are measured with, or referred to, a 1 m POF cable.

If transmission length less than 1 m, the SFH757's optical output power is higher than mentioned in the data sheet. For a 10 cm transmission length, the optical output power would be approximately 0.5 dB higher. If a longer transmission length is needed, the typical behavior of POF must be taken into account.

In the first few meters of POF cable, the effective fiber attenuation is about 0.5 dB/m, and only after this material-dependent distance is the typical attenuation of about 0.22 dB/m valid.

Suitable fiber cutting tools and polishing kits help to optimize the link performance, by decreasing optical insertion losses.

The effective fiber attenuation can be reduced by avoiding fiber bends and reducing the number of connections within the optical transmission line.

If all these preliminary considerations have been done, an actual power budget calculation can be made.

Transmission Line Planning

The following example demonstrates how a 30-meter PFC system should be constructed with an SFH551/1-1 receiver and SFH757 transmitter. The occuring pulse width distortion (PWD) of the SFH551/1-1 should be given special considered. Therefore adding a typical "3dB reserve" to the receiver´s limit sensitivity must be evaluted. This depends mainly on the data rate of the actual application. The calculations show how important it is to understand system requirements as well as the system effects of ambient temperature, link length, fiber installation, and product lifetime.

For typical application at TA=25° C:

Detector power (peak)	-22.0 dBm
Fiber attenuation (30 m distance with std. POF)	6.6 dB (0.22 dB/m)
Additional fiber attenuation of the first meters (approx.)	1.5 dB
Needed emitter power (peak) without tolerances	-13.9 dBm

A LED current of about 2.5 mA (peak) is needed for an optical output power of about -13.9 dBm (peak). Further effects which contribute to a reduction of the operating range should also be taken into account.

For an application operating from TA=-40°C to +85°C, the system aging effect(s) are:

Detector power (peak)	-17.0 dBm
Fiber attenuation (30 m distance witd std. POF)	6.6 dB (0.22 dB/m)
Additional fiber attenuation of the first few meters (approx.)	1.5 dB
Aging of fiber and known link disadvantages (e.g fiber bending)	1.0 dB
Aging of transmitter and receiver*	2.0 dB
Range of emitter power distribution over the whole temperature range	3.0 dB
Needed emitter power (peak)	-2.9 dBm

* The aging is application dependent (e.g. estimated lifetime of the end product). The aging effects apply mainly to the transmitter and very little to the receiver.

A LED current of about 20 mA (peak) is needed for a optical output power of about -2.9 dBm (peak).

The example calculations shown above are given for guidance only.

Recommendations for Mounting

When soldering ensure that the SFH component is not overheated. For A distance of 2 mm between the component and the soldering point (when using a soldering iron), the maximum permissible temperature is 260°C for at most 5 seconds.

With flow and dip soldering, the maximum temperature is also 260° C for up to a 5 seconds period.

When soldering particular care should be taken so that the component is not subject to any mechanical stress. When bending the connection pins, the packaging should not be loaded in any way.

The soldered components may be cleaned using organic solvents (with an alcohol base) a base of certain fluoro-hydrocarbons or a mixture of the two. Under no circum-stance should solvents or solvent mixtures be used which contain chlorohydrocarbons or ketones, because these can attack or dissolve the housing.

Reliability

Degradation

For optoelectronic emitters, the emitted radiation power reduces over the component's lifetime. This effect is known as ageing. It is dependent on the technology of the diode system, the load current I_f and the ambient temperature T_A.

The SFH757 is very reliable and no optical power degra-dation can be measured after 20000 continuos operation hours. (Test conditions: LED current = 50 mA (DC); TA=25° C)

Emitter Diode Permissible Current Load

When the emitter diode is in operation most of the electrical input power (U_f x I_f) is converted into heat. The temperature of the semiconductor chip and the packaging rises as a consequence. For reliability, the chip should not be heated above the maximum permitted for the depletion layer. This in turn yields a maximum power loss, dependent on the ambient temperature, which cannot be exceeded (refer to the relevant data sheets). These values are valid for DC operation.

Significantly better operating conditions are possible by using the emitter diode in pulse operation, as the average power decreases inversely proportional to the duty cycle. However this means that the maximum forward current I_f can be increased for shorter pulse widths and/or longer duty cycles.

Disclaimer

The information herein is given to describe certain components and shall not be considered as a guarantee of characteristics.

Terms of delivery and rights to technical change reserved.We hereby disclaim any and all warranties, including but not limited to warranties of non-infringement, regarding circuits, descriptions and charts stated herein.

Warnings

Due to technical requirements components may contain dangerous substances. For information on the types in-question please contact your nearest Avago Technologies Office.

Avago Technologies Components may only be used in life-support devices or systems with the express written approval of Avago Technologies, if a failure of such components can reasonably be expected to cause the failure of that life-support device or system, or to affect the safety or effectiveness of that device or system. Life support devices or systems are intended to be implanted in the human body, or to support and/or maintain and sus-tainand/or protect human life. If they fail, it is reasonable to assume that the health of the user or other persons maybe endangered.

Information

For further information on technology, delivery terms and conditions and prices please contact your nearest Avago Technologies Office (www.avagotech.com).

For product information and a complete list of distributors, please go to our web site: **www.avagotech.com**

AV02-2647EN - August 13, 2012