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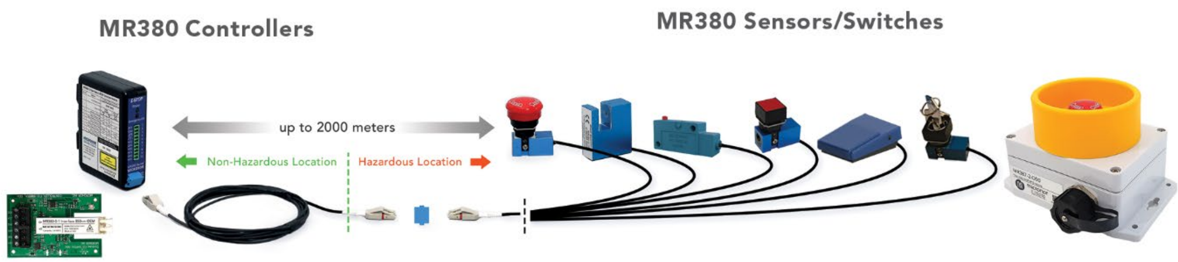
Application Note AN118

Determining System Loss Budget

Objective

This application note is intended to help users design their fiber optic sensor systems by calculating the System Loss Budget. A System Loss Budget is an estimate of loss in the fiber optic link which helps to verify that the optical link will function as designed.

This application note uses the MR386 FO Microswitch and MR386 FO Emergency Stop sensors as examples but applicable to all other Micronor FO sensors, including the MR330 series absolute and MR340 series incremental encoders.



Background

A fiber optic link consists of individual inline loss features; including cable segments, connectors, splices and sensors. The loss of each element must be accounted for when determining the System Loss Budget. Typical values for some of these elements are shown in *Table 1*.

As shown in *Table 1*, optical fiber exhibits different attenuation based on fiber size and operating wavelength of the controller. These values affect the overall loss budget and effective distance of the sensor system. The following is a simple guide to help determine the best layout for a specific system.

- Using multimode fiber and operating at 1310nm, the MR386 fiber optic microswitch or MR387 e-stop switch systems can operate up to 6.3km.
- Using single mode fiber and operating at 1310nm, the MR387 fiber optic e-stop systems can operate up to 20.5km.

Table 1: Typical Values for Computing System Loss Budget

Cable Specifications	Type of Fiber	Multi-Mode		Single-Mode
	Operating Wavelength (MR380-0-UNI or MR380-1-3 Controller)	1310nm		1310nm
	Fiber Size	OM2/OM3 50/125	OM1 62.5/125	OS1 SMF
Feature Losses	Fiber Loss	1dB/km	0.75dB/km	0.5dB/km
	One-Way Interconnect Loss Per Simplex LC Mating Adapter	0.5dB each		0.5dB each
	Two-Way Interconnect Loss Per Duplex LC or IP-LC Mating Adapter	1dB each		1dB each
	MR386 Sensor Loss (Multimode Only)	4dB	3.5dB	N/A
	MR387 Sensor Loss	3.5dB	2.5dB	5.0dB
Controller Loss Margins	MR380-0-UNI OEM	21dB		18dB
	MR380-1-3 DIN Rail	23dB		23dB

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Procedure for Calculating System Loss Budget

1. Identify Loss Margin for the selected controller
2. Calculate fiber loss at the operating wavelength of the controller
3. Account for each adapter loss excluding the connection to the controller
4. Double both fiber loss and connector loss to account for total round-trip loss
5. Include loss for any sensors used
6. Sum all losses and compare to Loss Margin from Step 1

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Example 1: Single E-Stop

Design requires the use of an MR387 E-Stop Sensor operating as a kill switch over a long distance. The link would consist of a 4km cable with direct connection to the MR380 DIN Rail Mount Controller as shown in *Figure 1*. Due to the distance being traveled, a OM1 62.5/125 Multimode Fiber was selected.

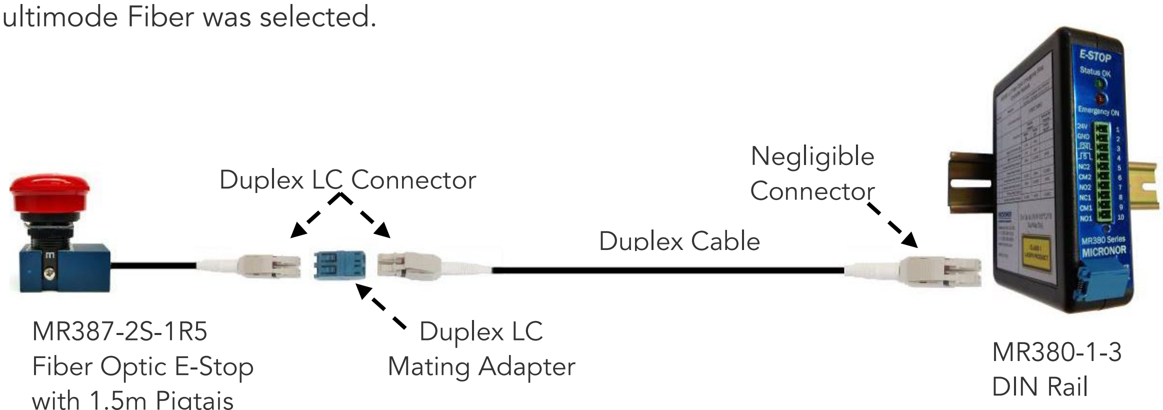

Figure 1: Configuration of Example 1

$$\text{Controller Loss Budget} \geq 2\text{x}\left[\begin{matrix}(\text{Fiber Loss} \times \text{distance}) + \\ (\text{Number of connectors} \times \text{Connector Loss})\end{matrix}\right] + \text{Sensor Loss}$$

Equation 1: Equation for calculating System Loss Budget

The following losses are located in *Table 1*, which originated from the datasheets for each product:

$$23\text{dB} \geq 2\text{x}\left[\left(\frac{0.75\text{dB}}{\text{km}} \times 4\text{km}\right) + \left(1\text{ connector} \times \frac{0.5\text{dB}}{\text{connector}}\right)\right] + 2.5\text{dB} = 10.5\text{dB}$$

$23dB \geq 10.5dB$ $\therefore$ The application is well within the System Loss Budget. Customer may proceed with their design.

As a further example, what is the maximum distance for a single E-Stop link - SM versus MM?

- **For multimode OM1 62.5/125 fiber:**

$$23\text{dB} \geq 2\text{x}\left[\left(\frac{0.75\text{dB}}{\text{km}} \times max\text{ km}\right) + \left(1\text{ connector} \times \frac{0.5\text{dB}}{\text{connector}}\right)\right] + 2.5\text{dB}$$

$$23\text{dB} \geq \left(\frac{0.75\text{dB}}{\text{km}} \times 2 \times max\text{ km}\right) + 3.5\text{dB},\ \boldsymbol{max}\ \textbf{km} = \left(\frac{\textbf{19.5dB}}{\frac{\textbf{0.75dB}}{\textbf{km}} \times \textbf{2}}\right) = \textbf{13 km}$$

- For single mode OS1 fiber:

$$23\text{dB} \geq 2\text{x}\left[\left(\frac{0.5\text{dB}}{\text{km}} \times max\ \text{km}\right) + \left(1\ \text{connector} \times \frac{0.5\text{dB}}{\text{connector}}\right)\right] + 5.0\text{dB}$$

$$23\text{dB} \geq \left(\frac{0.5\text{dB}}{\text{km}} \times 2 \times max\ \text{km}\right) + 6.0\text{dB},\ \boldsymbol{max}\ \mathbf{km} = \left(\frac{\mathbf{17dB}}{\frac{\mathbf{0.5dB}}{\mathbf{km}} \times \mathbf{2}}\right) = \mathbf{17\ km}$$

Example 2: Multiple E-Stops

As shown in *Figure 2,* the design requires the use of 4x MR387 E-Stop Sensors, 3 of which are located at a relatively short distance and one E-Stop is located 200m away. The client wishes to know if the design is feasible.

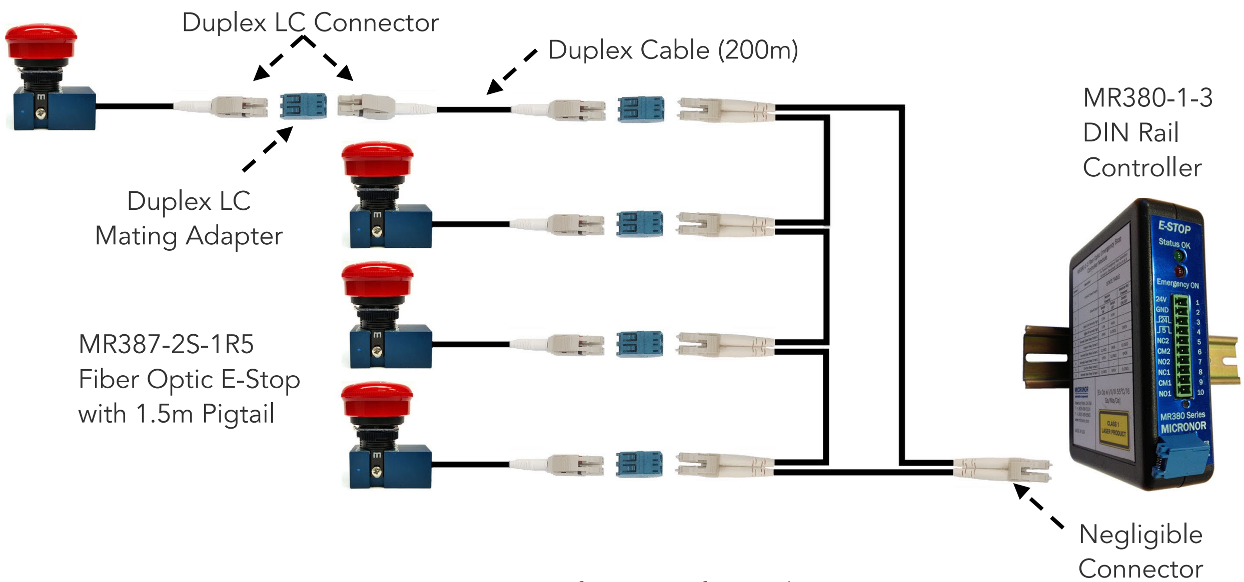

Figure 2: Configuration of Example 2

For this example, a 62.5/125 Multimode Fiber is being used and operating at 1310nm. Since the cabling, from the Controller to the main adapters, is short, their attenuation can be ignored. Therefore, the only applicable cable attenuation is from the 200m Duplex Cable.

Using *Table 1* and *Equation 1* provides:

$$23\text{dB} \geq 2\text{x}\left[\left(\frac{0.75\text{dB}}{\text{km}} \times .200\text{km}\right) + \left(5\ \text{connector} \times \frac{0.5\text{dB}}{\text{connector}}\right)\right] + (4\ \text{x}\ 2.5\text{dB}) = 16.2\text{dB}$$

$23\text{dB} \geq 16.2\text{dB}\ \therefore$ The application satisfies the required System Loss Budget

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Example 3: Mixed Sensors

This application is a customer's interlock design requires the use of 2x MR386 Microswitch and 1x MR387 E-Stop Sensor as shown in *Figure 3.* The client wishes to know the furthest distance the sensors can be placed away from the controller using a Multimode fiber.

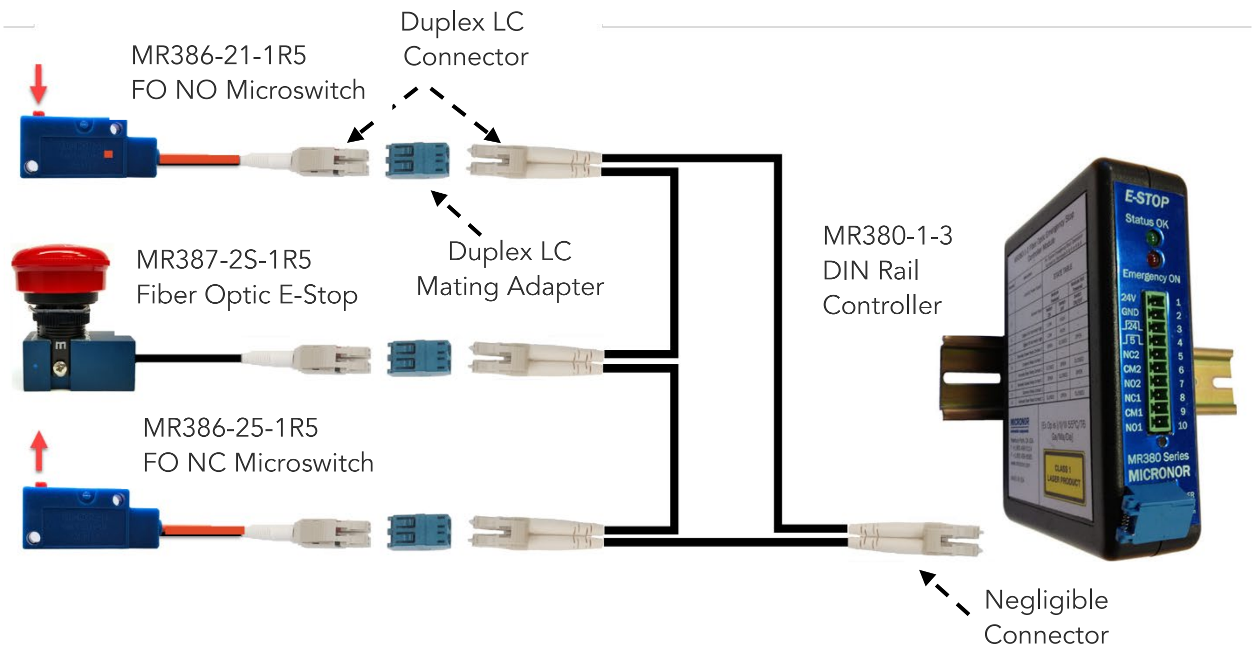

Figure 3: Configuration of Example 3

In order to maximize distance, a 62.5/125 Multimode Fiber is selected. It should be noted that all 3 sensors are located close to each other; therefore, the pigtail length losses can be ignored and only the round-trip attenuation of the cable from the controller is taken into consideration.

Using *Table 1* and *Equation 1* provides:

$$23\text{dB} \geq 2\text{x}\left[\left(\frac{0.75\text{dB}}{\text{km}} \times \text{max km}\right) + \left(3 \text{ connector} \times \frac{0.5\text{dB}}{\text{connector}}\right)\right] + (2 \text{ x } 3.5\text{dB}) + 2.5\text{dB}$$

$$23\text{dB} \geq \left(\frac{1.5\text{dB}}{\text{km}} \times \text{max km}\right) + 11.0\text{dB}$$

$\text{Max km} = 8.0 \text{ km} \therefore$ The maximum distance the client can place the sensors is 8.0 km away

Example 4: Extending Local E-Stop "Contacts" to Multiple Remote Locations

This application requires that a local E-Stop (or string of multiple E-Stops) communicates its emergency status (and dry contacts) to control related equipment in a remote location. To achieve this, the optical return signal from the E-Stop is split using a fiber optic 1x2 splitter (typical loss 3.5dB). It is recommended that this be done with singlemode fiber since SM splitters are less expension and more readily available then MM splitters.

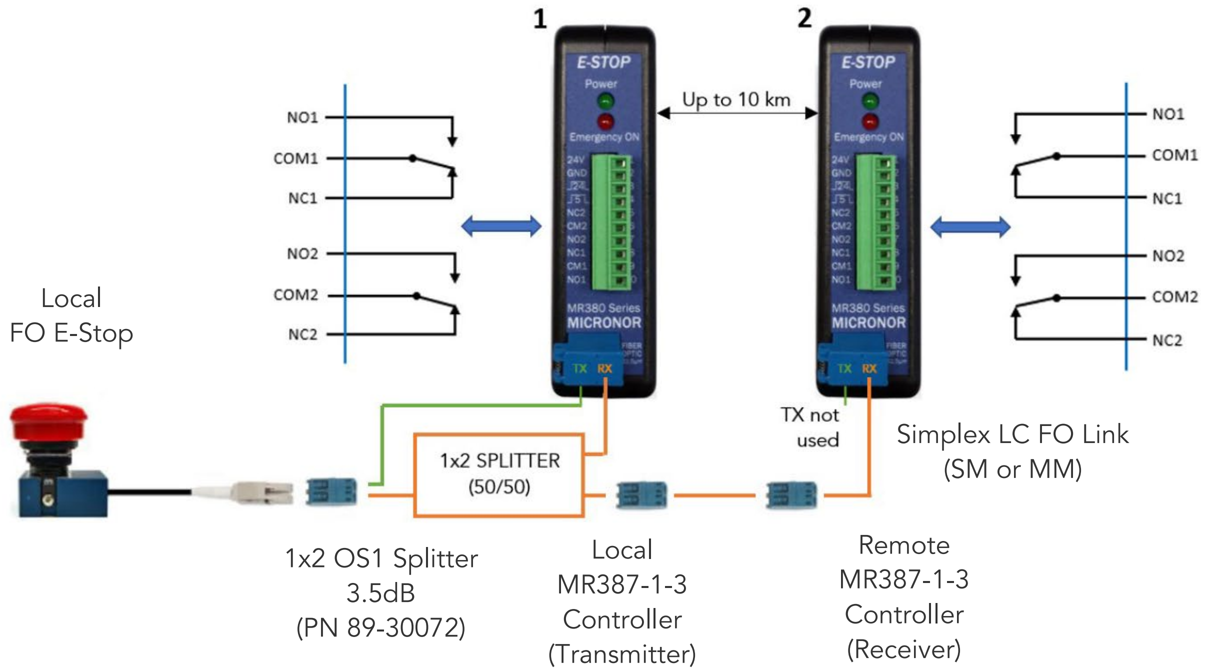

Figure 4: Configuration of Example 4

Assuming no interconnections, the maximum distance (SMF or MMF) is as follows:

Using *Table 1* and *Equation 1* and assuming OS1 SMF optical link:

$$23\text{dB} \geq \left[\left(\frac{0.5\text{dB}}{\text{km}} \times \text{max km}\right)\right] + \left(4 \text{ connectors x } \frac{0.5\text{dB}}{\text{connector}}\right) + 3.5\text{dB} + 5\text{dB}$$

$$23\text{dB} \geq \left(\frac{0.5\text{dB}}{\text{km}} \times \text{max km}\right) + 10.5\text{dB}$$

Max km = 21 km

Example 5: Extending The Reach Of An Electromechanical E-Stop

The MR387 Controllers can be used to provide an optical link for extending the reach of an existing electromechanical e-stop or switch. This application uses two MR387-1-3 Universal Controllers as an Fiber Optic Transmitter and Receiver System whereby the EM e-stop signals the remote Receiver by controlling the power to the local Transmitter module.

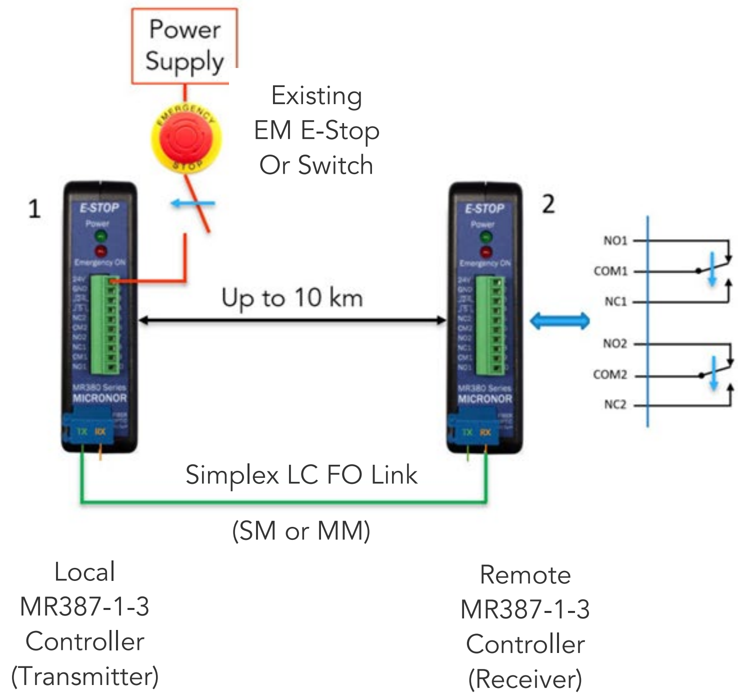

Figure 5: Configuration of Example 5

Assuming no interconnections, the maximum distance (SMF or MMF) is as follows:

Using *Table 1* and *Equation 1* and assuming one-way OS1 SMF optical link:

$$23\text{dB} \geq \left[\left(\frac{0.5\text{dB}}{\text{km}} \times \text{max km}\right) + \left(0 \text{ connector} \times \frac{0.5\text{dB}}{\text{connector}}\right)\right] = 0.5\text{dB/km}$$

$$23\text{dB} \geq \left(\frac{0.5\text{dB}}{\text{km}} \times \text{max km}\right) = \text{max \_46km for OS1 SMF}$$

Using *Table 1* and *Equation 1* and assuming one-way OM1 62.5/125 MMF optical link:

$$23\text{dB} \geq \left[\left(\frac{0.75\text{dB}}{\text{km}} \times \text{max km}\right) + \left(0 \text{ connector} \times \frac{0.5\text{dB}}{\text{connector}}\right)\right] = 0.75\text{dB/km}$$

$$23\text{dB} \geq \left(\frac{0.75\text{dB}}{\text{km}} \times \text{max km}\right) = \text{max } 30.7\text{km for OM1 MMF}$$

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User Guidance

- Poor installation practices and poor quality connectors and splices can contribute additional losses that will cause the link to not operate properly.
- After installation, an optical loss test should be performed to determine the actual system link loss versus the calculated link loss.
- Carefully clean and inspect connectors before mating.
- Fiber optic connectors do not require maintenance, i.e. do not detach working connections to clean.
- Only open connections if you believe a problem exists.
- Do not mix fiber sizes in an installation

For sales or technical support, contact Micronor Sensors at +1-805-389-6600 or support@micronor.com