User's Manual

# MOST50 E-O Converter

# Further Information

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# Legend

# Conventions

Within this manual, the following abbreviations and symbols are used to improve readability.

| Example | Description |
|---|---|
| **BIT** | Name of a single bit within a field |
| **FIELD.BIT** | Name of a single bit (BIT) in FIELD |
| x…y | Range from x to y, inclusive |
| **BITS[m:n]** | Groups of bits from m to n, inclusive |
| **PIN** | Pin Name |
| msb, lsb | Most significant bit, least significant bit |
| MSB, LSB | Most significant byte, least significant byte |
| zzzzb | Binary number (value zzzz) |
| 0xzzz | Hexadecimal number (value zzz) |
| zzh | Hexadecimal number (value zz) |
| rsvd | Reserved memory location. Must write 0, read value indeterminate |
| `code` | Instruction code, or API function or parameter |
| *Multi Word Name* | Used for multiple words that are considered a single unit, such as: *Resource Allocate* message, or *Connection Label*, or *Decrement Stack Pointer* instruction. |
| *Section Name* | Section or Document name. |
| $\overline{\text{VAL}}$ | Over-bar indicates active low pin or register bit |
| x | Don't care |
| <Parameter> | <> indicate a Parameter is optional or is only used under some conditions |
| {,Parameter} | Braces indicate Parameter(s) that repeat one or more times. |
| [Parameter] | Brackets indicate a nested Parameter. This Parameter is not real and actually decodes into one or more real parameters. |

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# 1 Preface

## 1.1 Intended Use

SMSC's MOST50 E-O Converter is intended for use during development, test, and analysis of MOST50 Electrical Physical Layer (ePHY) network devices. Operation of the MOST50 E-O Converter is supported only when used in conjunction with the components provide by SMSC, which are included in the product deliverables (see Section 1.2). The original state of the product should not be altered; otherwise product functionality and performance cannot be guaranteed, and user safety may be at risk.

This user's manual should be read in its entirety prior to operating the MOST50 E-O Converter, with special consideration given to Initial Charge Instructions (Appendix C). Any reference to E-O Converter in this document implies MOST50 E-O Converter.

## 1.2 Deliverables

The MOST50 E-O Converter is designed for use with the components that accompany the device in the MOST50 E-O Converter Kit. A complete MOST50 E-O Converter Kit includes the following items:

- MOST50 E-O Converter (qty: 2)
- 12 V Power Supply (qty: 2)
- Unshielded Twisted Pair (UTP) ePHY Cable - 0.5 m (qty: 2)
- Duplex Optical Fiber Cable - 3 m (qty: 1)
- Duplex Optical Fiber Cable - 40 m (qty: 1)
- ePHY Connector Housing (qty: 2)
- Female Contacts (qty: 8)
- MOST50 E-O Converter User's Manual (qty: 1)

# 2 Introduction

In order to validate electomagnetic compatibility (EMC) and operational electrostatic discharge (ESD) tests, it is necessary to isolate the device under test (DUT) from other nodes within the MOST50 ePHY network (see Figure 2-1). Isolation involves eliminating the influence of the other nodes as well as external environmental factors from the DUT. In the case of EMC testing, environmental isolation is achieved through the use of an anechoic chamber, which is a shielded room that is designed to attenuate environmental noise sources. For operational ESD testing, the transient voltages induced on the ePHY network need to be confined to the DUT. This is accomplished by electrically isolating the DUT ePHY network from the other MOST50 devices.

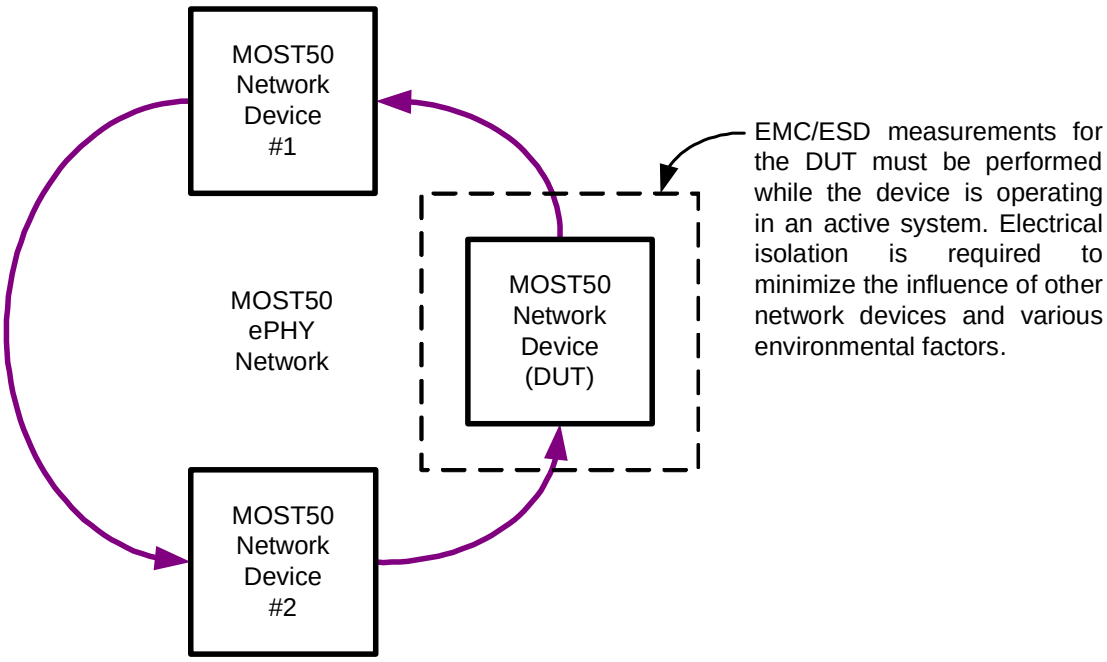


**Figure 2-1: MOST50 Network Implementation**

The MOST50 E-O Converter assists in isolating the DUT during a functional network test by converting a MOST50 ePHY network into an optical physical layer network interface. Figure 2-2 shows how this is achieved by using two E-O Converter devices. One E-O Converter is connected electrically to the MOST50 network devices *outside* of the test environment while the other E-O Converter is connected electrically to the MOST50 DUT *inside* of the test environment. The MOST50 network is completed when an optical connection is made between the two E-O Converters.

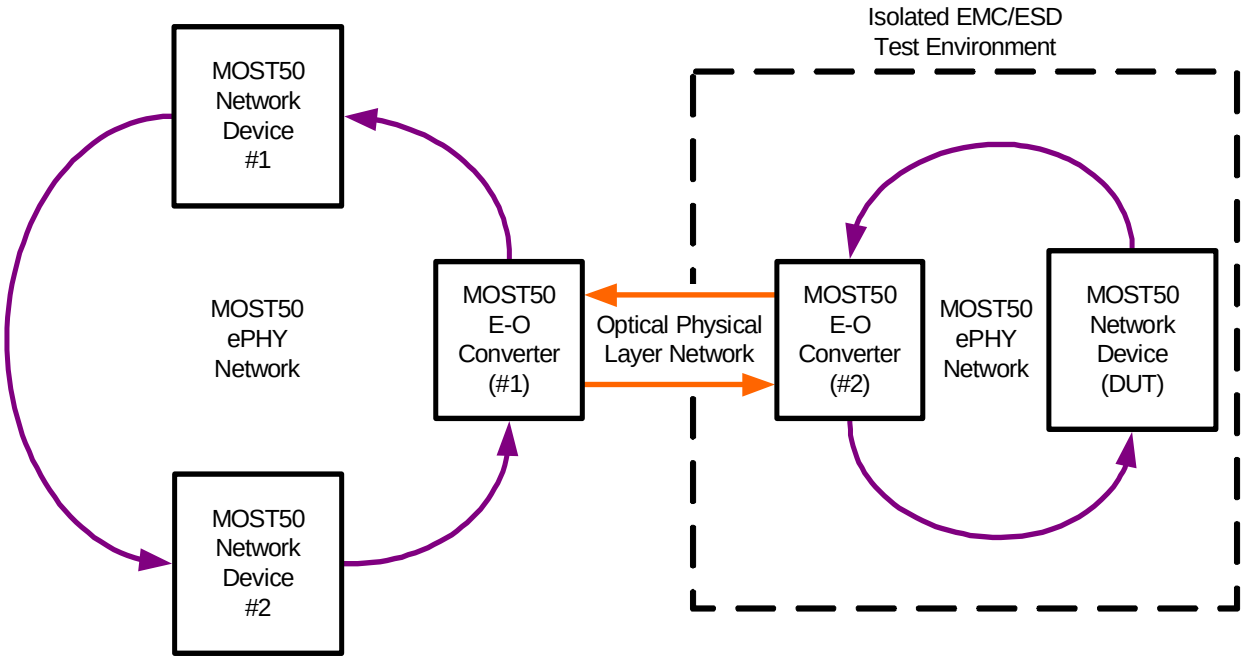


**Figure 2-2: MOST50 Network Implementation with DUT Isolation**

The major features of the MOST50 E-O Converter include:

- Conversion between MOST50 ePHY network signals and optical physical layer network signals
- Minimal influence on MOST50 ePHY network messages
- Protection of stimulus equipment from harsh test environments
- Optical interface operable at lengths up to 50 m
- Aluminum enclosure with battery power supply to reduce emissions and improve immunity
- On-board battery charger circuit
- Simultaneous battery charging and powering the device
- Low battery indicator
- Remote monitoring of ePHY errors through a *Versatile Link* optical transmitter

The MOST50 E-O Converter has been tested under the following conditions:

- CISPR 25:2002
  – Radiated and Conducted Emissions: Class 5, narrowband
- ISO 11452-3:2001(E)
  – 225 V/m, 1 - 400 MHz
- ISO 11452-4:2001
  – 200 mA, no network unlocks or coding errors
  – 300 mA, no physical damage
- ISO 10605:2001
  – Handling: ±8 kV contact discharge
  – Operational: ±15 kV air discharge

# 3 System Example

Instructions on setting up a sample test system are provided in this section. The test system, shown in Figure 3-1, utilizes two MOST50 E-O Converters to electrically isolate an OS81082 Evaluation Board, which is the DUT in this sample system. The test environment in this example is represented by the anechoic chamber. The OptoLyzer G2 3050e serves as the MOST50 network master and is used to monitor and inject network traffic through either OptoLyzer transceiver or MOST RapidControl.

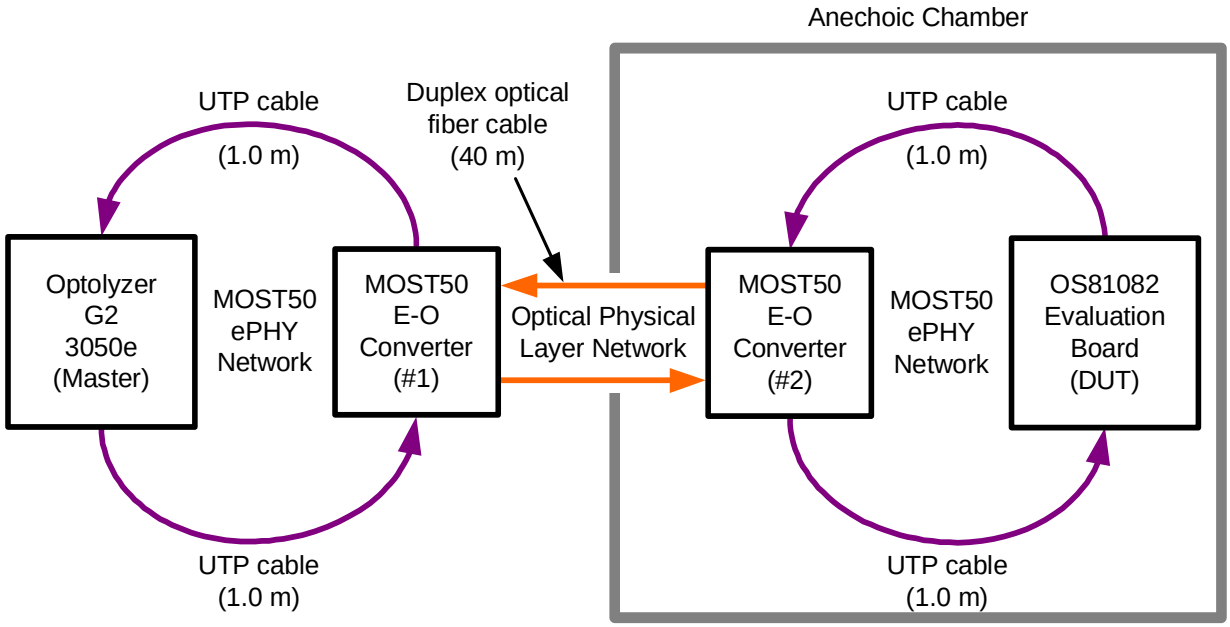


**Figure 3-1: MOST50 Test System Example**

Devices used in the test system example (Figure 3-1) are connected using the following steps. Cable connections between devices are shown in Figure 3-2.

1. Connect the OS81082 Evaluation Board (DUT) to the E-O Converter (#2) with two UTP ePHY cables.
2. Connect the duplex optical fiber cable to each of the E-O Converters, ensuring that the SC connectors are inserted correctly.
3. Connect the OptoLyzer G2 3050e (Master) to the E-O Converter (#1) using two more UTP ePHY cables.
4. Turn on all of the devices. The ePHY and optical error LEDs on the E-O Converters will turn off once the network is locked.
5. The system is now ready for testing.

In this example, the Optolyzer G2 3050e is able to exercise the DUT without adding any noise interference. The test can also include any number of MOST50 network devices within the anechoic chamber.

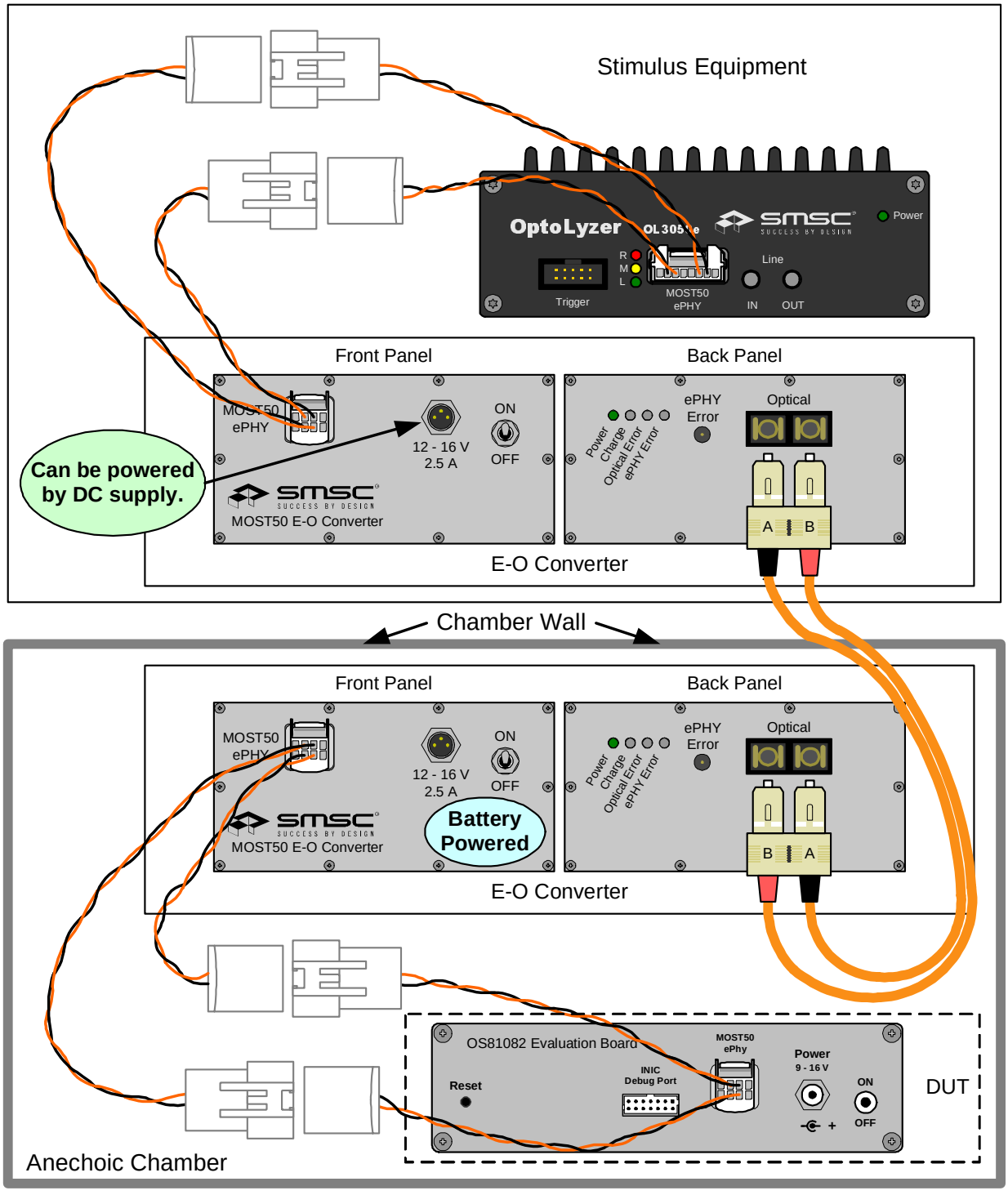


**Figure 3-2: Connection Diagram**

# 4 Board Details

An overview of the MOST50 E-O Converter PCB is shown in Figure 4-1. The E-O Converter provides a single power jack for supplying power (12 V, 2.5 A typical) to the entire E-O Converter. This jack supports a power plug such as Binder 99-3400-100-03 (or equivalent). Alternatively, the E-O Converter power can be supplied by an internal battery. Power from the battery or external power supply, can be completely disconnected from the functional circuitry by the power switch. The power switch must be in the *ON* position in order for the E-O Converter to function.

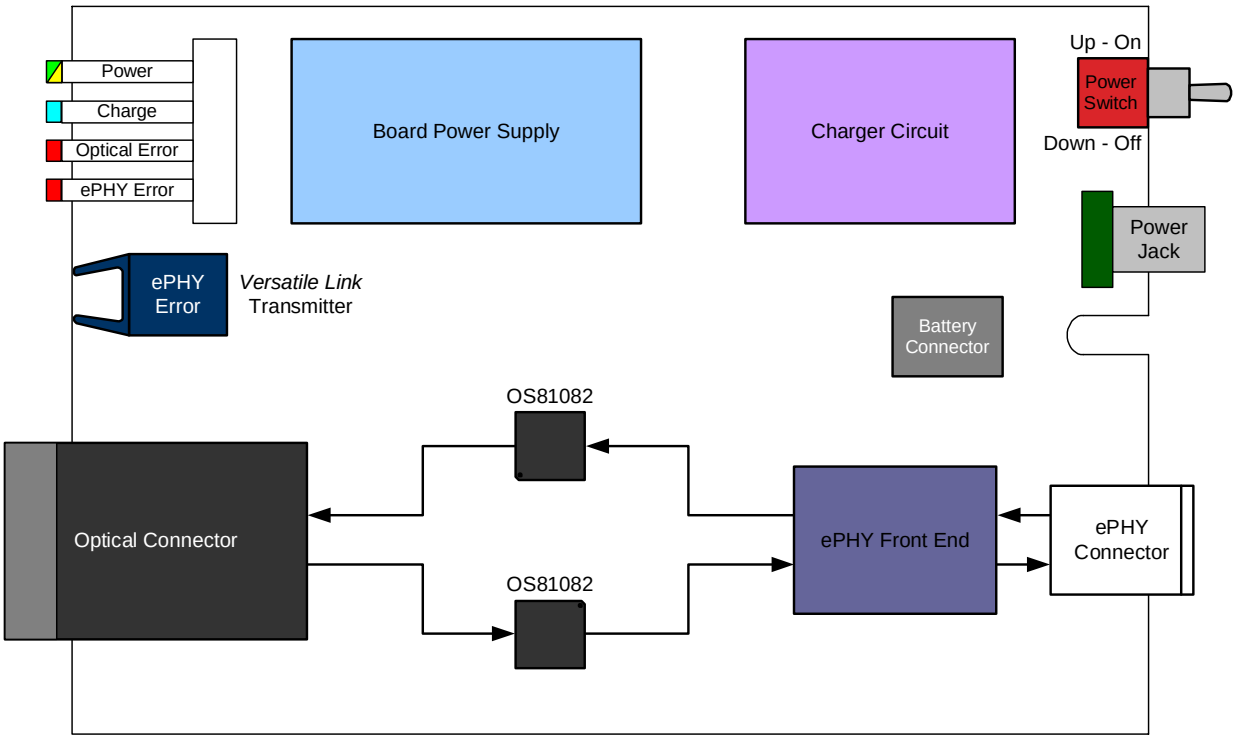


**Figure 4-1: E-O Converter PCB Block Diagram**

## 4.1 Battery Operation

An on-board charger circuit is provided, which allows the battery to charge when a DC power supply is present at the power jack. The charger circuit automatically turns on when a DC power supply is inserted into the power jack, independent of the power switch. When the fast-charge conditions are met, the charger circuit begins to fast-charge the battery. Fast-charge is active when the *Charge* LED (blue) is on. If the battery reaches a temperature greater than 50 °C the charger circuit exits the fast-charge cycle. The fast-charge cycle typically lasts three to four hours when the battery is completely discharged. The end of the fast-charge cycle is indicated by the *Charge* LED turning off. Anytime that the *Charge* LED is off and the DC power supply is connected to the E-O Converter, the charger circuit trickle-charges the battery. Trickle-charge mode helps to maintain a full charge on the battery without over-charging it.

Inserting a DC power supply into an E-O Converter with a full charge on its battery results in a short fast-charge cycle. A temperature monitor ensures that the charger circuit does not enter fast-charge until the battery temperature is less than 40 °C. The *Charge* LED will flash to indicate that the battery cannot enter fast-charge mode. The *Charge* LED stops flashing once the battery temperature falls below 40 °C.

If the battery is severely depleted of charge and the DC power supply is plugged into the E-O Converter, a pre-charge will occur to condition the battery for a fast-charge cycle. This pre-charge condition is also signified by the *Charge* LED flashing. Once the battery reaches a minimum voltage, the charger will commence with the fast-charge cycle.

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The E-O Converter uses a nickel-metal hydride rechargeable battery, therefore it is not necessary to fully discharge the battery before it can be recharged.

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When the power switch is in the *ON* position and the DC power supply is connected to the power jack, the DC power supply powers the board supplies (3.3 V and 2.5 V) for the functional circuitry (data conversion). Operation of the E-O Converter while the battery is charging can be a useful feature during compliance testing. The E-O Converter *outside* of the test environment can be powered by a DC power supply, which ensures that its battery maintains a full charge. When the battery of the E-O Converter *inside* of the test environment is low, indicated by the *Power* LED (yellow) on, the *inside* and *outside* E-O Converters can be switched to allow the empty battery to charge while testing continues. Switching the E-O Converters in this manner results in minimal down time, and can easily be done between tests.

Once the DC power supply is disconnected, the charger circuit shuts down. If the power switch is *ON* when this occurs, the board power supplies will continue to be powered by the battery. A full battery charge typically provides 10 hours of power for MOST50 E-O Converter operation. After approximately eight hours, the low battery indicator *Power* LED (yellow) turns on. This indicates that there are less than two hours of battery life remaining and that the battery should be recharged.

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To conserve battery charge, the power switch should be turned *OFF* whenever tests are not being conducted.

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## 4.2 Physical Layer Conversion

The primary function of the MOST50 E-O Converter is network signal conversion between electrical and optical physical layers. The E-O Converter incorporates two OS81082 *Intelligent Network Interface Controllers* (INICs) to achieve this conversion. The network frame rate of both ePHY and optical physical layer networks is 48 kHz. One INIC receives the incoming ePHY network signal and retransmits it as the outgoing optical physical layer network signal; the other INIC receives the incoming optical physical layer network signal and retransmits it as the outgoing ePHY network signal. This ePHY to optical physical layer conversion is accomplished by re-clocking the MOST50 network signal while maintaining data integrity.

The optical physical layer signal is a pseudo MOST50 interface that is based on *Positive Emitter Coupled Logic* (PECL). Since the optical physical layer network produces no emissions and is isolated electrically, it can be routed through the EMC chamber wall and connected to another E-O Converter, where it is converted back to an ePHY network signal. The optical physical layer interface consists of a 1300 nm wavelength optical physical layer transceiver with a SC duplex receptacle. This allows the signal to be transmitted over multi-mode, 62.5/125 µm glass optical fiber cable for distances up to 50 m. The MOST50 E-O Converters can be integrated into larger chambers without adding any significant delay to the network.

The incoming ePHY and optical physical layer network signals are checked for coding errors and network unlocks. Any time an ePHY network error occurs, the *ePHY Error* LED (red) is pulsed on. Any time an optical physical layer network error occurs, the *Optical Error* LED (red) is pulsed on. A coding error is indicated by an LED (*ePHY Error* or *Optical Error*) pulse length greater than 50 ms, while a network unlock event produces a pulse length greater than 150 ms. ePHY network errors are also conveyed from the *Versatile Link* optical transmitter (see Figure 4-2). A *Versatile Link* optical receiver, along with a plastic optical fiber (POF) cable can be used to capture ePHY network errors that occur during testing. This is especially useful for automated *Bulk Current Injection* (BCI) and *Transverse Electromagnetic* (TEM) cell testing, outlined in Sections 5.2 and 5.3. The pulse lengths of the ePHY network errors transmitted from the *Versatile Link* optical transmitter are the same as ePHY network errors on the *ePHY Error* LED.

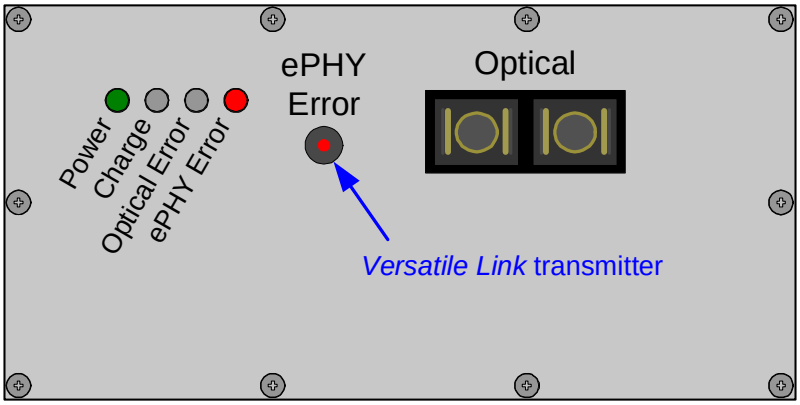



**Figure 4-2: Versatile Link Transmitter (ePHY Error)**

## 4.3 Status LEDs

The E-O Converter provides four status LEDs: *Power*, *Charge*, *Optical Error*, and *ePHY Error*. In addition, the *ePHY Error* *Versatile Link* transmitter provides status similar to the *ePHY Error* LED. The status LEDs and *Versatile Link* transmitter are shown in Figure 4-3.

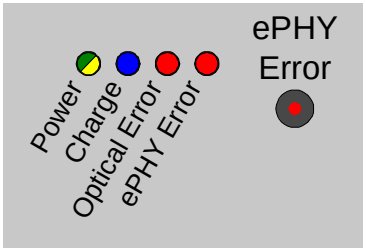



**Figure 4-3: LED Layout**

### 4.3.1 Power

The *Power* LED provides four states that convey the following status information:

- *Off* - The E-O Converter is not powered (power switch is *OFF* or battery charge is depleted).
- *Green* - The E-O Converter is powered via the battery or the power jack (power switch is *ON*).
- *Yellow* - The battery has less than two hours of charge remaining. Use the DC power supply to charge the battery.
- *Flashing Green/Yellow* - The battery is disconnected or defective (DC power supply is present).

### 4.3.2 Charge

The *Charge* LED is relevant only when the DC power supply is connected to the power jack. The three states of the *Charge* LED include:

- *Off* - The battery is in trickle-charge mode. This indicates that the fast charge cycle has completed and the battery is fully charged.
- *Blue* - The charger circuit is in fast-charge mode.
- *Flashing Blue* - The battery cannot enter fast-charge mode because the temperature is too high or the battery is severely discharged. In this mode, the battery is being trickle charged.

### 4.3.3 Optical Error

The *Optical Error* LED is only valid while the E-O Converter is powered (*Power* LED is green). The two states for the *Optical Error* LED include:

- *Off* - There are no coding errors or network unlocks from the incoming optical network.
- *Red* - A coding error or network unlock event occurred on the incoming optical network. The pulse width of the on cycle is greater than 50 ms for coding errors and greater than 150 ms for network unlock events. The *Optical Error* LED is constantly on while the error condition persists.

### 4.3.4 ePHY Error

The *ePHY Error* LED and *Versatile Link* transmitter are only valid when the E-O Converter is powered (*Power* LED is green). The two states for the *ePHY Error* LED and *Versatile Link* transmitter include:

- *Off* - There are no coding errors or network unlocks from the incoming ePHY network.
- *Red* - A coding error or network unlock event occurred on the incoming ePHY network. The pulse width of the on cycle is greater than 50 ms for coding errors and greater than 150 ms for network unlock events. The *ePHY Error* LED and *Versatile Link* transmitter are constantly on while the error condition persists.

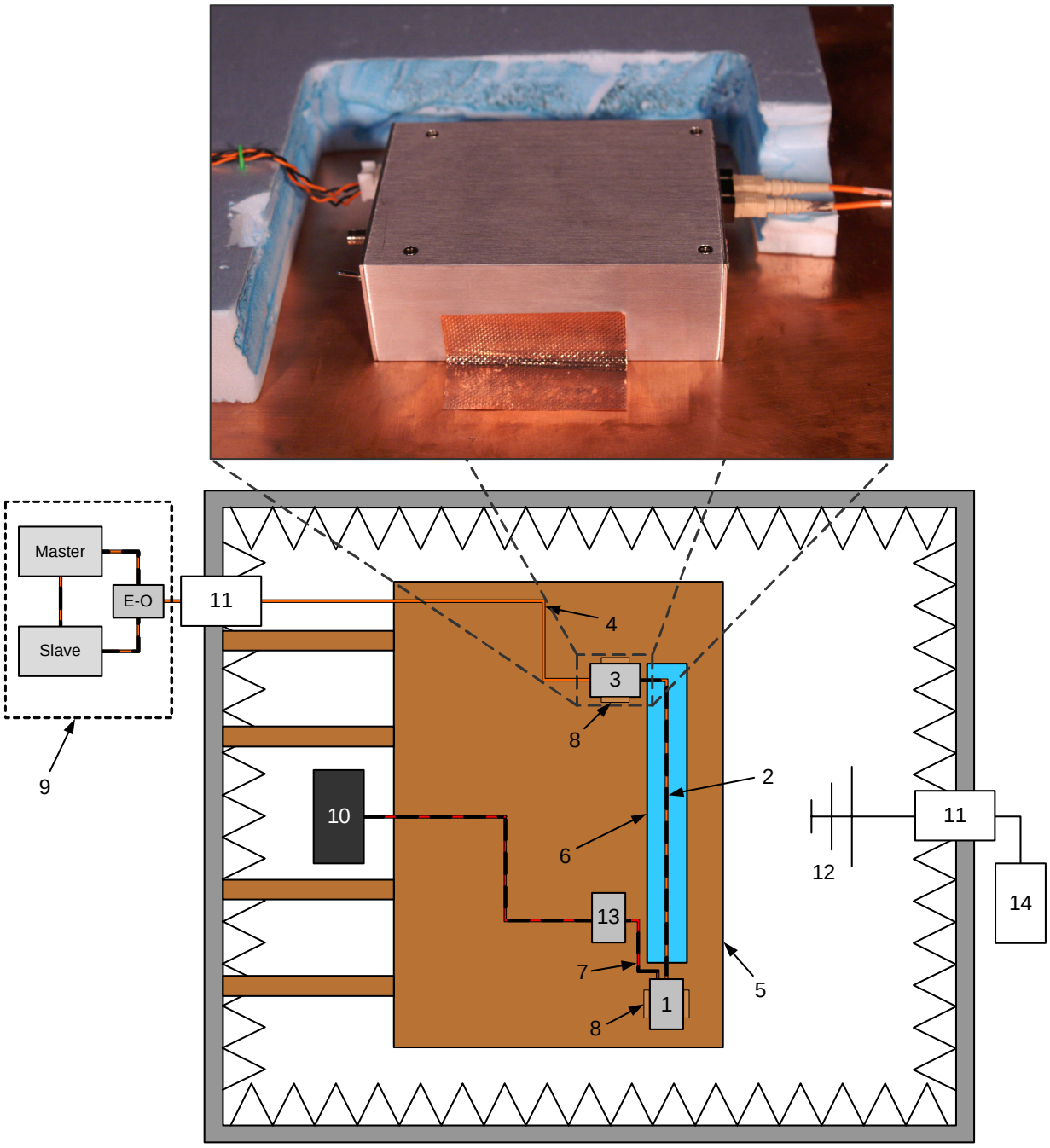
# 5 Test Configurations

The MOST50 E-O Converter can be used in a variety of tests. This chapter provides four test configuration examples, each using a pair of E-O Converters to electrically isolate the device under test from the other network components. The test configurations provided can be used for:

- Radiated Emissions
- Bulk Current Injection (BCI)
- Transverse Electromagnetic (TEM) Cell
- Operational Electrostatic Discharge (ESD)

## 5.1 Radiated Emissions

Figure 5-1 shows a sample CISPR 25:2002 style test configuration for radiated emissions testing. Two E-O Converters are used in the configuration. One is connected electrically to the DUT inside of the anechoic chamber; the other is connected to the stimulus equipment outside of the anechoic chamber. A glass optical fiber cable connects the E-O Converters together, isolating any radiated noise from the stimulus equipment. The E-O Converter is grounded to the ground plane to minimize unwanted emissions. Figure 5-1 shows that copper tape was used to ground the E-O Converter to the ground plane inside of the chamber. A picture of the E-O Converter is shown to further clarify how it is connected inside the chamber. Outside the chamber, the stimulus equipment, including all other nodes that are a part of the actual application, are connected to the MOST50 network. An OptoLyzer G2 3050e may also be used outside the chamber to monitor all MOST50 traffic.



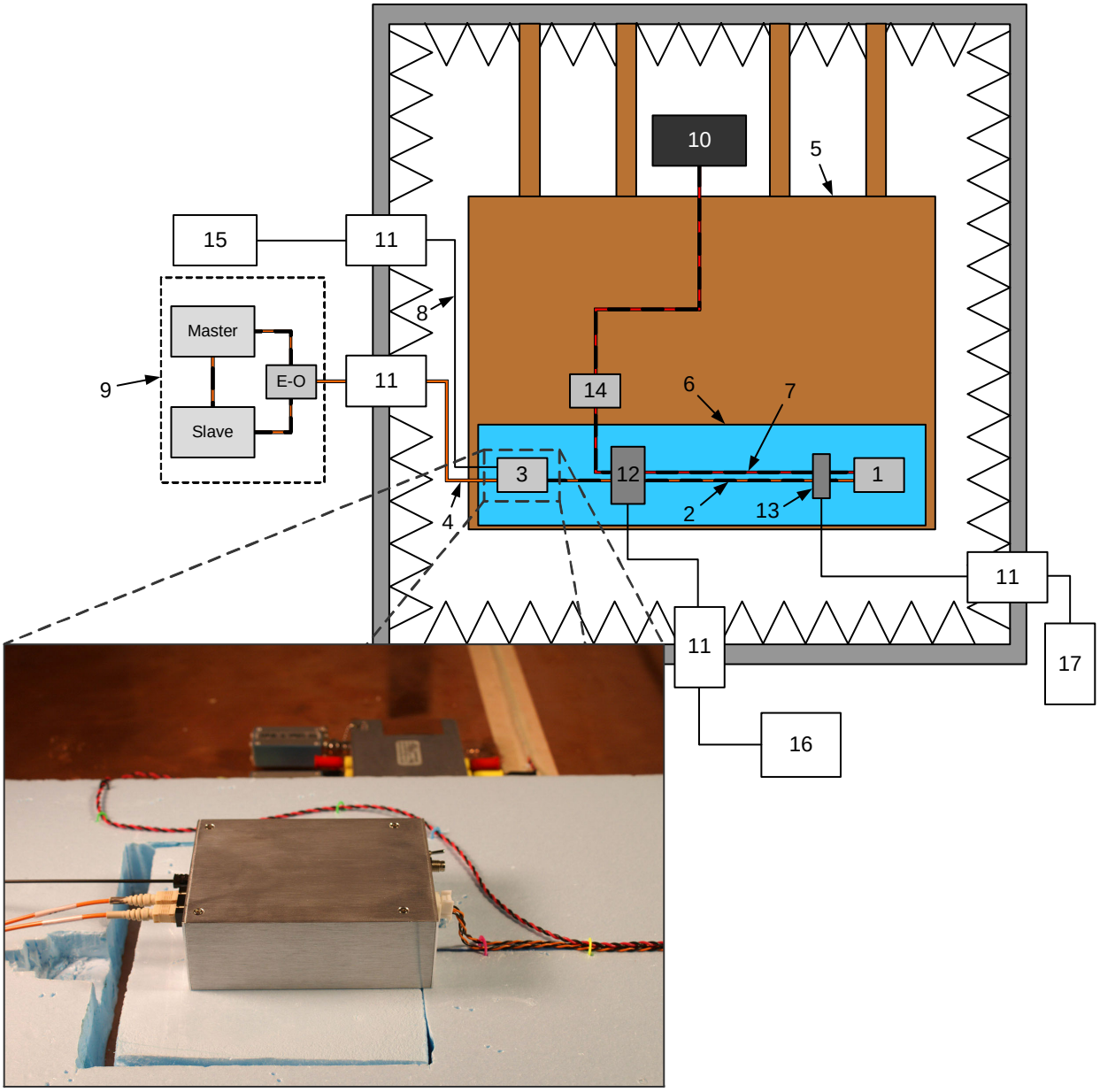

| | |
|---|---|
| 1. DUT | 9. Stimulus Equipment (Including E-O Converter) |
| 2. ePHY Cable | |
| 3. MOST50 E-O Converter | 10. 12 V Battery |
| 4. Glass Optical Fiber (SC Duplex) | 11. Feedthru |
| 5. Ground Plane | 12. Antenna |
| 6. Insulating Support | 13. LISN |
| 7. DUT Power Cable | 14. Test Receiver |
| 8. Copper Tape (to ground plane) | |

**Figure 5-1: Radiated Emissions Test Setup**

## 5.2 Bulk Current Injection

Figure 5-2 shows a sample ISO 11452-4:2001 test configuration for BCI testing. For immunity tests, the E-O Converter inside the anechoic chamber is isolated from the ground plane by floating it on an insulating support. This ensures that RF energy is dissipated by the DUT and not the E-O Converter. For automated BCI testing, the E-O Converter's *ePHY Error Versatile Link* transmitter output is connected by a POF cable with *Versatile Link* connectors to a *Versatile Link* receiver outside of the chamber. Both network coding errors and unlock events are indicated on the *ePHY Error* output and can be monitored and recorded at the *Versatile Link* receiver.

Refer to Appendix A for *Versatile Link* receiver and POF cable specifications.

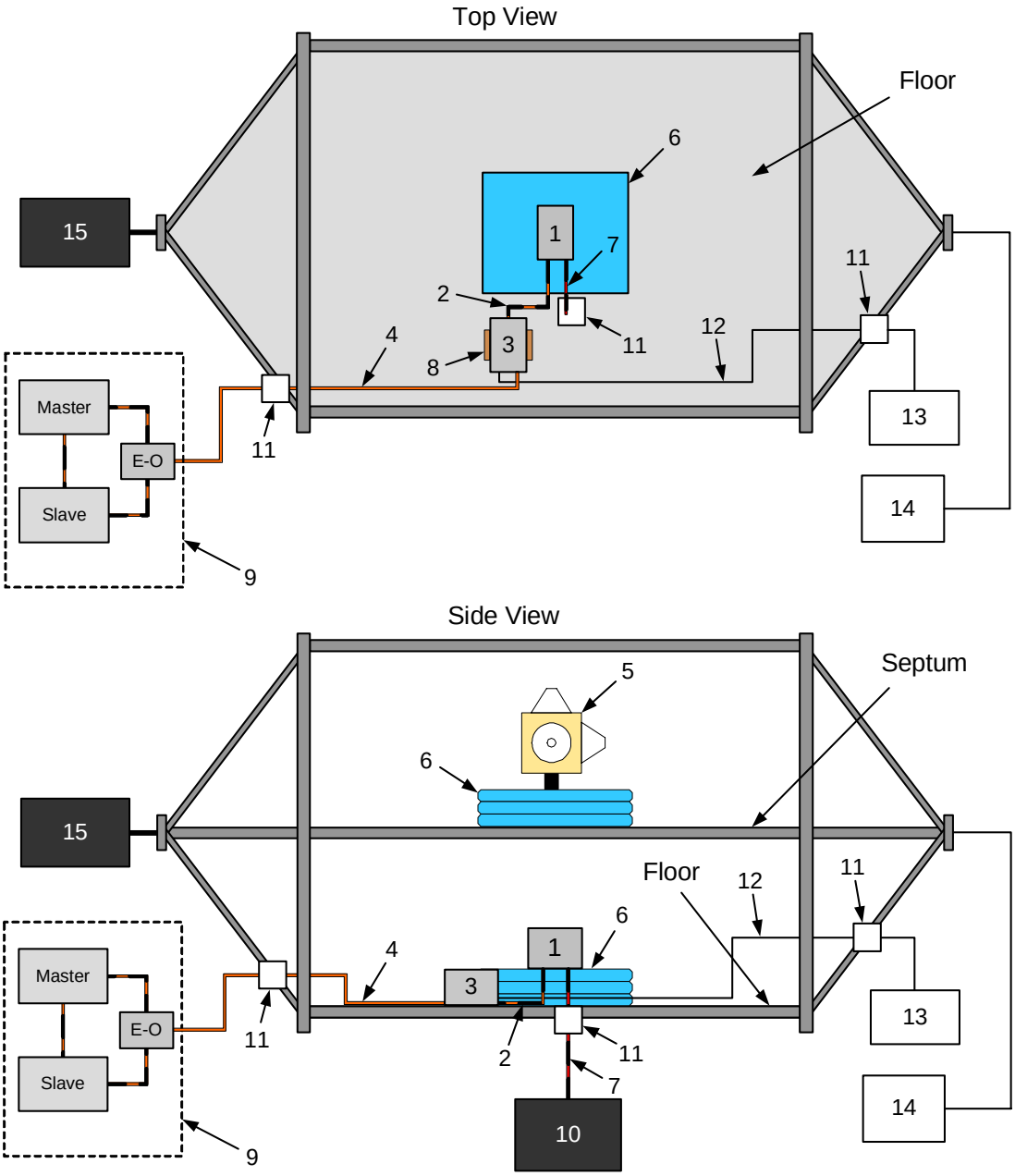



| | |
|---|---|
| 1. DUT | 10. 12 V Battery |
| 2. ePHY Cable | 11. Feedthru |
| 3. MOST50 E-O Converter | 12. Current Injection Probe |
| 4. Glass Optical Fiber (SC Duplex) | 13. Current Monitoring Probe |
| 5. Ground Plane | 14. LISN |
| 6. Insulating Support | 15. *ePHY Error* Monitoring Receiver |
| 7. DUT Power Cable | 16. RF Source |
| 8. Plastic Optical Fiber | 17. Test Receiver |
| 9. Stimulus Equipment (Including E-O Converter) | |

**Figure 5-2: BCI Test Setup**

## 5.3 Transverse Electromagnetic Cell

Figure 5-3 shows the top and side views for a sample test configuration of an ISO 11452-3:2001(E) style TEM cell test. The glass optical fiber isolates and protects the stimulus equipment from the electrical disturbances produced during testing. The E-O Converter inside of the TEM cell is grounded to the metal floor using copper tape. For automated TEM Cell testing, the E-O Converter's *ePHY Error Versatile Link* transmitter output is connected by a POF cable with *Versatile Link* connectors to a *Versatile Link* receiver outside of the TEM cell. Both network coding errors and unlock events are indicated on the *ePHY Error* output and can be monitored and recorded at the *Versatile Link* receiver. Figure 5-4 shows a photograph of a typical TEM cell test configuration.




| | |
|---|---|
| 1. DUT | 9. Stimulus Equipment (Including E-O Converter) |
| 2. ePHY Cable | |
| 3. MOST50 E-O Converter | 10. 12 V Battery |
| 4. Glass Optical Fiber (SC Duplex) | 11. Feedthru |
| 5. Field Probe | 12. Plastic Optical Fiber |
| 6. Insulating Support | 13. *ePHY Error* Monitoring Receiver |
| 7. DUT Power Cable | 14. RF Source |
| 8. Copper Tape (to TEM Cell Floor) | 15. 50 Ω Load |

**Figure 5-3: TEM Cell Test Setup**

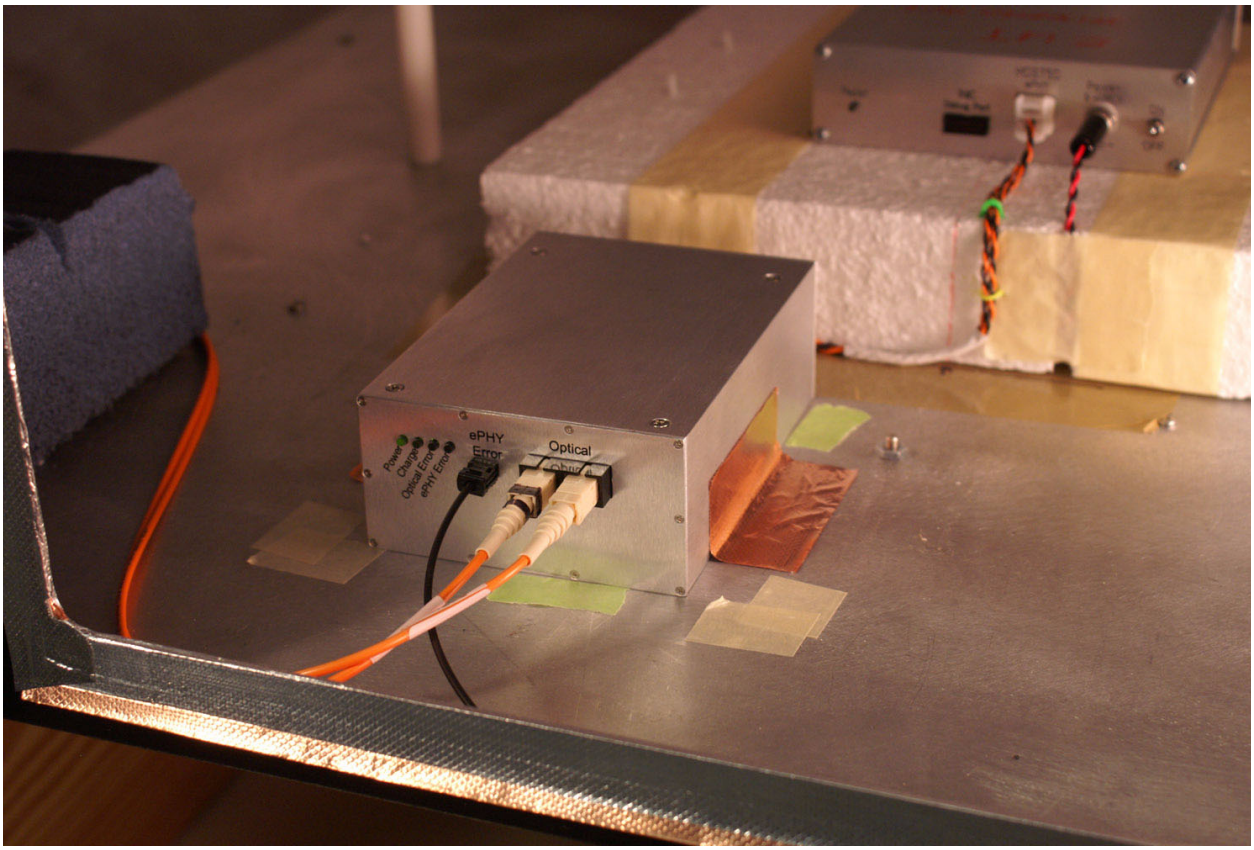
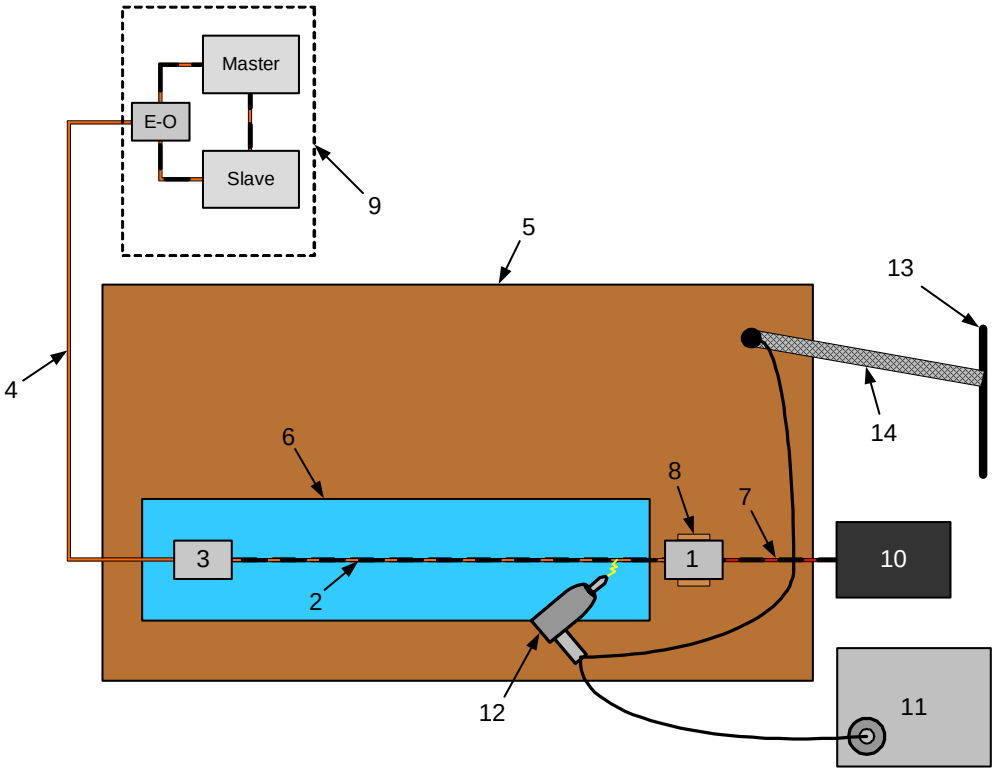



**Figure 5-4: Typical E-O Converter TEM Cell Setup**

## 5.4 Electrostatic Discharge

Figure 5-5 shows a sample test configuration for an ISO 10605:2001 operational ESD test. The glass optical fiber isolates the stimulus equipment from the high-voltage transients that are induced on the DUT. The E-O Converter *inside* the test environment is isolated from the ground plane using an insulating support. Grounding only the DUT, with copper tape, ensures that the ESD events induced on the ePHY network are dissipated solely through the DUT.




| | |
|---|---|
| 1. DUT | 9. Stimulus Equipment (Including E-O Converter) |
| 2. ePHY Cable | |
| 3. MOST50 E-O Converter | 10.12 V Battery |
| 4. Glass Optical Fiber (SC Duplex) | 11. ESD Simulator |
| 5. Ground Plane | 12. ESD Gun |
| 6. Insulating Support | 13. Building Ground |
| 7. DUT Power Cable | 14. Ground Strap |
| 8. Copper Tape (to Ground Plane) | |

**Figure 5-5: Operational ESD Test Setup**

# Appendix A: Specifications

| Description | Min | Typ | Max | Units | Conditions |
|---|---|---|---|---|---|
| ***MOST50 E-O Converter:*** | | | | | |
| Input Voltage | 12 | | 16 | V (DC) | |
| Input Current | | | 2.5 | A (DC) | $V_{in}$ = 12 V (DC) |
| Operating Temperature | 0 | | 50 | °C | |
| ***Fast Charge Cycle:*** | | | | | |
| Input Current | | 2.0 | | A (DC) | power switch off |
| Charge Time | | 150 | 200 | min. | |
| Temperature Cut-off | | | 50 | °C | |
| ***Trickle Charge Cycle:*** | | | | | |
| Input Current | | 2.0 | | A (DC) | power switch off, during pulse |
| Period | | 1.17 | | s | |
| Pulse Width | | 73 | | ms | |
| ***Battery Pack (7 Cells, 4/3 A in Series):*** | | | | | |
| Output Voltage | | 8.4 | 10.5 | V (DC) | |
| Capacity | 3.7 | 3.75 | | Ah | |
| Temperature Fuse | | | 60 | °C | |
| ***Optical Transceiver (Duplex, SC Receptacle):*** | | | | | |
| Output Optical Power | | | -14 | dBm avg. | 62.5/125 µm fiber |
| Data Rate | | 50 | | Mb/s | |
| Wavelength | | 1300 | | nm | |
| Transmission Length | | | 50 | m | |
| ***ePHY Error (Versatile Link Transmitter):*** | | | | | |
| Pulse Length | 50 | | | ms | |
| Output Optical Power | | | -15 | dBm | |
| Wavelength | | 660 | | nm | |
| ***Versatile Link Optical Receiver (Avago HFBR-25X3Z or Equivalent) (Not Included):*** | | | | | |
| Supply Voltage | | 3.3 | | V (DC) | |
| Input Optical Power | -39 | | | dBm | LED on |
| Data Rate | DC | | 1.0 | kHz | |
| Wavelength | | 660 | | nm | |
| ***Versatile Link Plastic Optical Fiber Cable (Avago Connectors: HFBR-4531Z or equivalent) (Not Included):*** | | | | | |
| Fiber Diameter | | 1.0 | | mm | core and cladding |
| Fiber Attenuation | | | 0.2 | dB/m | |
| Cable Length | | | 50 | m | |
| ***12 V DC Power Supply:*** | | | | | |
| Input Voltage | 100 | | 240 | V (AC) | 50 - 60 Hz |
| Input Current | | 1.5 | | A (AC) | |
| Output Voltage | | 12 | | V (DC) | |
| Output Current | | 3.75 | | A (DC) | |

**Table A-1: Specifications**

# Appendix B: Troubleshooting

| Problem | Solution |
|---|---|
| E-O Converter does not power on | - Plug in the DC power supply and check if the E-O Converter powers up.<br>- If it now works, the *Power* LED (green) will turn on. Also, the *Charge* LED (blue) will turn on or flash.<br>- If the *Charge* LED does not turn on or flash, the battery is defective.<br>- If neither of these works, the power supply might not be operating correctly. Check that the green LED is on for the 12 V power supply. |
| Network does not lock | - Check the *Optical Error* and *ePHY Error* LEDs on the E-O Converters.<br>- If the *Optical Error* LED is on, make sure that the glass optical fiber cable is hooked up correctly and the connections are securely in place.<br>- If the *ePHY Error* LED is on, make sure that the ePHY cable is hooked up correctly and the connections are securely in place.<br>- If neither of these works, make sure that the network has a timing-master. |
| *Charge* LED is flashing | - The battery is severely depleted of charge and a pre-charge is needed. The charger will begin a fast-charge cycle when a minimum voltage is reached.<br>- The battery has recently been charged and is outside of the temperature range to enter another fast-charge cycle. The unit is ready to be used. |
| *Power* LED is flashing green and yellow | The battery is malfunctioning or has become disconnected. |
| *ePHY Error* *Versatile Link* transmitter is not working | - The *Versatile Link* transmitter should be lit at the same time as the *ePHY Error* LED.<br>- If they both turn on, make sure that the plastic fiber optical cable is connected correctly and that the *Versatile Link* receiver meets the specifications listed in Appendix A.<br>- If the *Versatile Link* transmitter does not turn on while the *ePHY Error* LED is on, then the transmitter is malfunctioning. |
| Battery charge does not last more than eight hours, or the low battery indicator turns on prematurely | - The battery is faulty and should be replaced. |
| Something is rattling inside of the enclosure | - The LED lightpipe is loose by design. Check to see that the rattling is not caused by the LED lightpipe by holding a finger on the lightpipe and gently shaking the enclosure.<br>- If it is not the lightpipe, then something else is loose inside the enclosure and could cause a short to the battery. Do not operate the E-O Converter. |

**Table 5-1: Troubleshooting**

# Appendix C: Initial Charge Instructions

Before using the MOST50 E-O Converter, a full charge cycle must be completed as follows:

1. Turn *OFF* the power switch.
2. Connect the 12 V power supply to the power jack. The *Charge* LED (blue) will turn on, indicating a fast-charge cycle is in progress.
3. Wait until the *Charge* LED turns off. The initial charge may take three to four hours to complete.

Once the initial charge is complete the E-O Converter is ready to use.

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To ensure maximum battery life, do not disconnect the 12 V power supply until the fast-charge cycle is complete.

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**NOTES:**


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