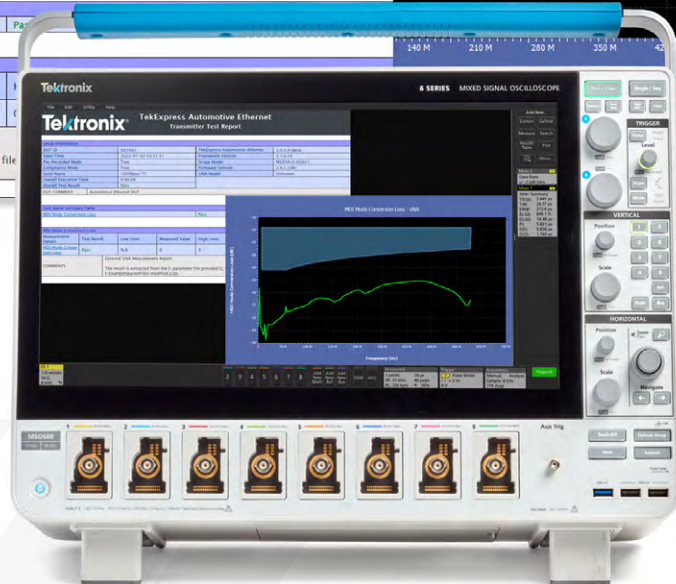


# Measuring MDI Mode Conversion Loss For Automotive Ethernet Compliance

## APPLICATION NOTE

| Tektronix® TekExpress Automotive Ethernet Transmitter Test Report                                                         |                     |                                |                |
|---------------------------------------------------------------------------------------------------------------------------|---------------------|--------------------------------|----------------|
| Setup Information                                                                                                         |                     |                                |                |
| DUT ID                                                                                                                    | DUT001              | TekExpress Automotive-Ethernet | 1.5.5.4 (Beta) |
| Date/Time                                                                                                                 | 2023-07-07 03:51:51 | Framework Version              | 5.7.0.33       |
| Pre-Recorded Mode                                                                                                         | True                | Scope Model                    | MSO58 (2.0GHz) |
| Compliance Mode                                                                                                           | True                | Firmware Version               | 2.4.1.1081     |
| Suite Name                                                                                                                | 1000Base-T1         | VNA Model                      | Unknown        |
| Overall Execution Time                                                                                                    | 0:00:04             |                                |                |
| Overall Test Result                                                                                                       | Pass                |                                |                |
| DUT COMMENT: Automotive Ethernet DUT                                                                                      |                     |                                |                |
| Test Name Summary Table                                                                                                   |                     |                                |                |
| MDI Mode Conversion Loss                                                                                                  |                     |                                |                |
| MDI Mode Conversion Loss                                                                                                  |                     |                                |                |
| Measurement Details                                                                                                       | Test Result         | Low Limit                      | Measured Value |
| MDI Mode Conversion Loss                                                                                                  | Pass                | N.A.                           | 0              |
| COMMENTS                                                                                                                  |                     |                                |                |
| External VNA Measurement Report<br>The result is extracted from the S-parameter file t:\ExampleSparamFiles\modified.s2p). |                     |                                |                |



## Abstract

Data speed requirements for In-Vehicle Networks (IVN) continue to grow as auto safety and entertainment systems like Advance Driver Assistance Systems (ADAS) and cockpit infotainment systems become faster and more sophisticated. Manufacturers are transitioning to automotive Ethernet for in-vehicle networks to support the data speed performance required for these new systems. To ensure that Ethernet equipment operates correctly in the automotive network, components like transmitters, receivers, and cables/connector assemblies must pass a series of compliance tests.

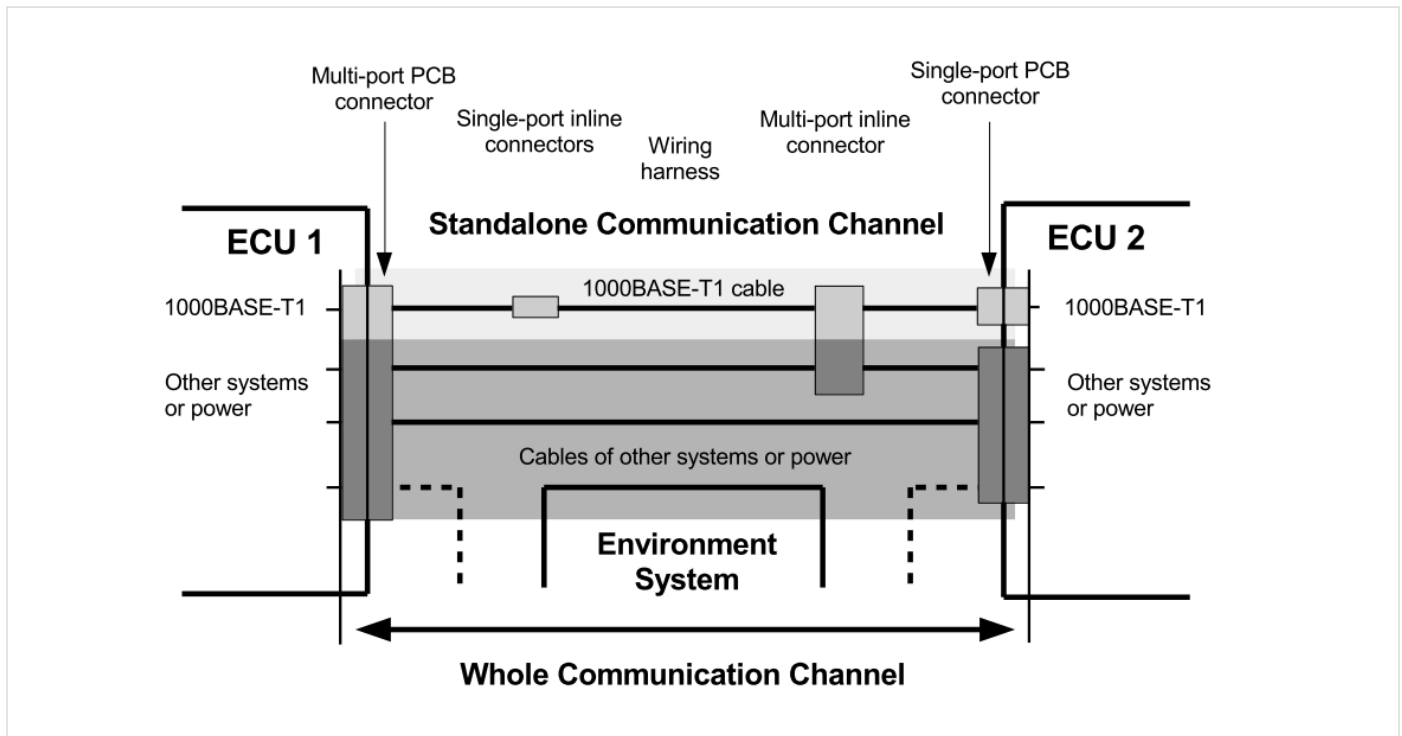
The MDI Mode Conversion Loss measurement ensures the compliance of the Common mode EMI/EMC generated by the ECU-to-ECU communications.

## Introduction

The IEEE P802.3bw D3.3 and IEEE P802.3bp standards identify several compliance tests to ensure equipment interoperability.

Media Dependent Interface (MDI) Mode Conversion Loss is a crucial test. The common-to-differential mode and differential-to-common mode conversion specifications are intended to limit the amount of unwanted signal energy that is allowed to be generated due to the conversion of common-mode-voltage-to-differential-mode-voltage or vice versa. This test evaluates the loss of an MDI under test to confirm that the reflected power remains below set limits over specific frequency ranges which are defined in the standards.

The MDI mode conversion loss measurements are typically performed with a Vector Network Analyzer's (VNA) Port 1 and 2 performing the Mode Conversion loss measurement.



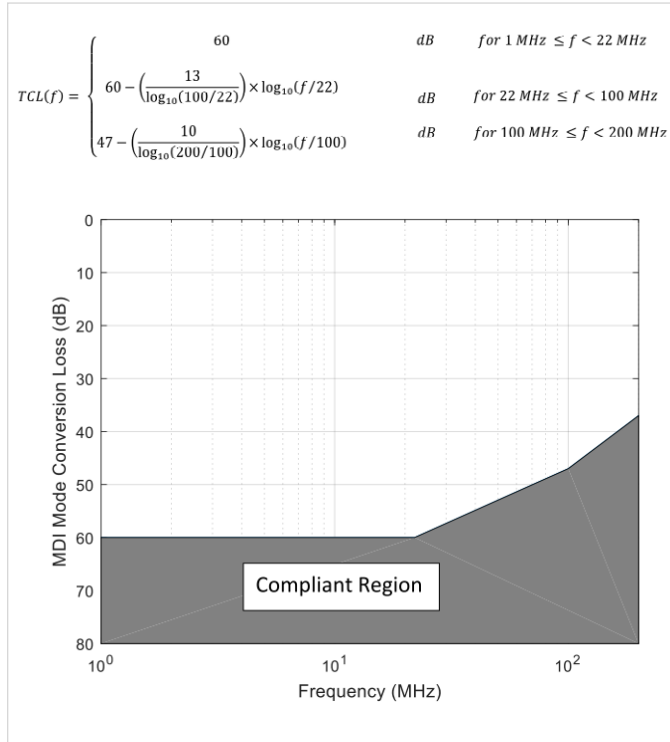
Source: Open Alliance

## Technical Insight

A compliant 100BASE-T1 / 1000BASE-T1 device shall ideally have a differential characteristic impedance of 100Ω; however, mismatches in the positive and negative polarities of the MDI output will introduce mode conversion.

In wired signal transmission, conversion between the differential and common modes deteriorates the quality of the transmitted signal and causes electromagnetic compatibility problems in the environment. Therefore, the transmission-line components are requested to be tested for their conversion loss characteristics, such as the longitudinal conversion loss (LCL), transverse conversion loss (TCL), and mixed-mode S-parameters.

The common-mode-to-differential-mode conversion TCL and TCTL (defined in S-parameters: Sdc11, Sdc22, Sdc21, and Sdc12) of the link segment for 100BASE-T1 MD shall meet or exceed the following equation for all frequencies from 1 MHz to 200 MHz:



### 100BASE-T1 Compliant Region: LCL (Sdc11), TCL (Scd11).

longitudinal conversion loss (**LCL**) and transverse conversion loss (**TCL**) mode conversion for 1000BASE-T1 link segment, LCL (Sdc11) or TCL (Scd11) of the PHY measured at MDI shall meet the values determined using equation at all frequencies ranging from 10 MHz to 600 MHz:

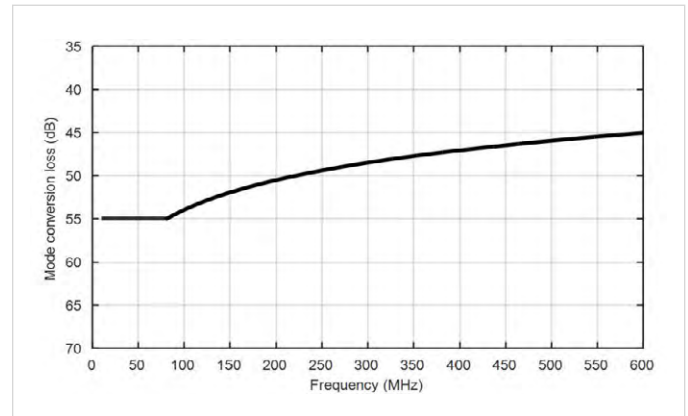
$$\text{ConversionLoss}(f) \geq \begin{cases} 55 & 10 \leq f \leq 80 \\ 77 - 11.51 \log_{10} f & 80 < f \leq 600 \end{cases} \text{ dB}$$

where

$f$  is the frequency in MHz;  $10 \leq f \leq 600$

The mode conversion specification applies to:

- Longitudinal conversion loss (LCL) with s-parameter SDC11/SDC22 and description of common mode to differential mode return loss  
 $20 \cdot \log_{10}(\text{abs } 0.5 \cdot (S_{11} + S_{12} - s_{21} - S_{22}))$
- Transverse conversion loss (TCL) with s-parameter SCD11/SCD22 and description differential mode to common mode return loss
- Longitudinal conversion transmission loss (LCTL) with s-parameter SDC12/SDC21 and description common mode to differential mode insertion loss
- Transverse conversion transmission loss (TCTL) with s-parameter SCD12/SCD21 and description differential mode to common mode insertion loss



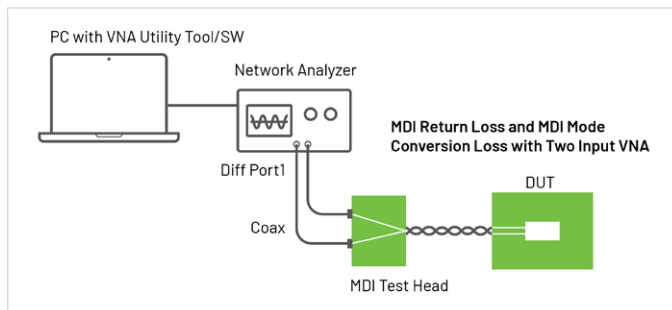
1000BASE-T1 Compliant Region

## Recommended Test Setup

Note: The MDI mode conversion loss measurements are typically performed with a Vector Network Analyzer (VNA). Depending on the design of the VNA there may only be a single input port, if this is the case a balun will need to be used to convert the differential transmission of the DUT to a single-ended input for the VNA. However, if the VNA has two or more input ports a balun is not necessary.

When using a VNA, the MDI Mode Conversion Loss measurement must be performed on a multi-port network analyzer. When measuring mode conversion loss, the impedance balance of the cabling and test fixtures in the test setup is critical. In addition to the test fixtures used, it is highly recommended that a reference ground plane is placed under the test setup, and securely connected to the test fixture for sufficient grounding. Any fixtures used to connect the MDI of the DUT to the test equipment should have enough mode conversion loss margin compared to the MDI requirement.

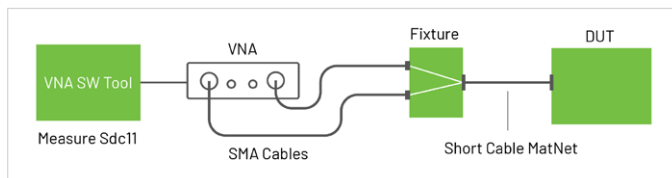
### Typical Setup



In the VNA, set the start and stop frequencies for testing. In accordance with the Open Alliance specifications, the appropriate frequency ranges must be selected based on the automotive ethernet bit rate:

| Data Rate   | Start Frequency | Stop Frequency |
|-------------|-----------------|----------------|
| 100BASE-T1  | 300 KHz         | 66 MHz         |
| 1000BASE-T1 | 1 MHz           | 1000 MHz       |

### Actual Setup



## MDI Mode Conversion Loss Test Report Integration Guide

The TekExpress automotive solution for 100 Base-T1 / 1000 Base-T1 provides an option to integrate the external result of MDI Mode Conversion Loss (MCL) to a TekExpress report.

The solution provides an option to choose a specific S2P file format (which has Sdc11(Re/Im)) to browse. This solution reads the Sdc11 Real and Imaginary values, converts them into dBm unit, and plots against the compliance limit.

### MDI Mode Conversation Loss Test S2P File Format

The solution expects the S2P file in the following format only:

```
!Freq Sdd11: Re/Im Sdc11: Re/Im Scd11: Re/Im
Scc11: Re/Im
```

```
# Hz S R I R 50
```

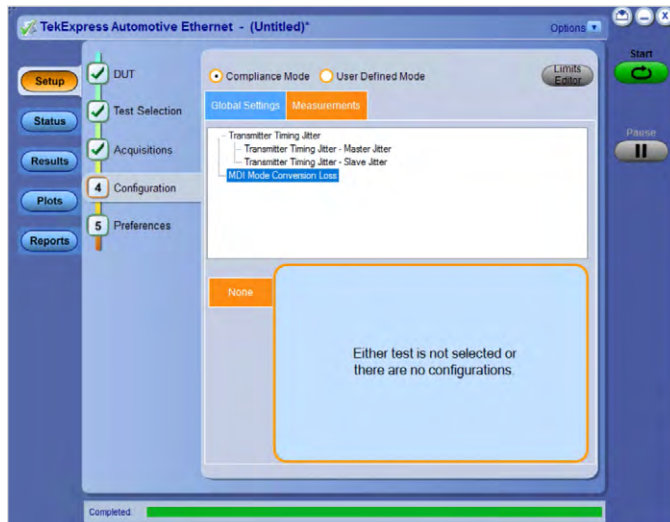
The solution just assumes the Sdc11 is in 2nd place and its Re/Im at columns 4 and 5 respectively. Typical values are shown below.

```
!Freq Sdd11: Re/Im Sdc11: Re/Im Scd11: Re/Im Scc11: Re/Im
# Hz S R I R 50
3.00000000E+05 3.42949793E-02 -5.45207859E-02 -1.69233003E-03 1.89603165E-03 -1.43617389E-03 2.68125362E-03 7.43583425E-01 2.71751253E-01
3.29850000E+06 -5.18687295E-02 6.65671342E-03 1.81436483E-02 1.09954551E-02 1.34712758E-02 -1.31590543E-02 7.95012790E-01 4.35403997E-02
6.29700000E+06 -1.06090604E-02 -2.01409283E-02 2.47342985E-04 -2.39323412E-03 -1.93048488E-04 3.24118576E-05 8.88858073E-01 -2.28935726E-02
9.29550000E+06 -1.32605366E-02 -2.40028100E-02 -3.60961572E-05 -2.30821079E-03 -2.61963845E-04 2.45757172E-04 8.86339999E-01 -5.31124458E-02
1.22940000E+07 -1.60502571E-02 -2.78706611E-02 -3.06143127E-04 -1.69950520E-03 9.06620162E-05 -0.22334303E-04 0.79926039E-01 -0.00065460E-02
1.52925000E+07 -1.94723812E-02 -3.16367277E-02 -6.96749636E-04 -1.36841563E-03 -2.75383371E-04 -1.15532076E-03 8.69156873E-01 -1.04265526E-01
1.82910000E+07 -2.35257130E-02 -3.45817579E-02 -1.38070641E-03 -2.51070351E-03 3.02207325E-04 -1.12884683E-03 8.55095616E-01 -1.24888101E-01
2.12095000E+07 -2.75730432E-02 -3.72104775E-02 -2.13075110E-04 -1.16262545E-03 -1.06141344E-03 -1.01464940E-03 0.36737200E-01 -1.41550119E-01
2.42880000E+07 -3.17941792E-02 -3.96991282E-02 -1.06928337E-04 -2.12887903E-03 -9.55015385E-04 -1.21231334E-03 8.15903747E-01 -1.51274660E-01
```

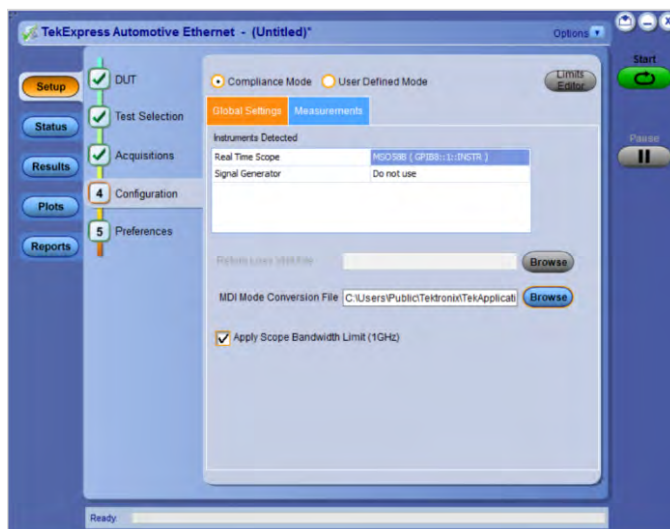
## Configuration of MDI MCL Test

For 100 Base-T1 or 1000Base-T1 Test

- Go to the “DUT Panel” and select the Suite.
- Go to the “Test Panel” as below and select the Test



- Click on MDI Mode Conversion S2p “Browse” option.



- Perform run.
- The report will be generated with all details.



### MDI Mode Conversion TekExpress Report

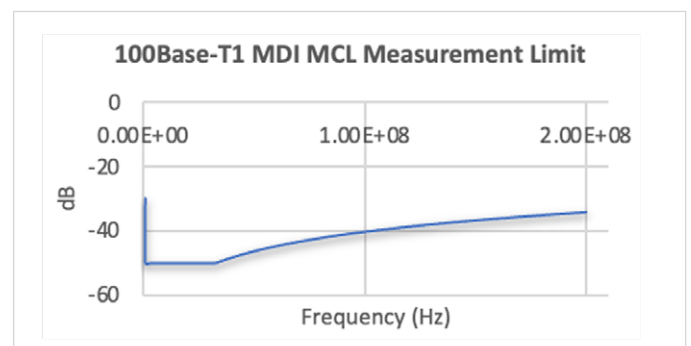
### 100BASE-T1 MDI Mode Conversion Loss (MCL) Test Limit

$$\text{MDI mode conversion loss}(f) \geq \left\{ 50 - 20 \times \log_{10} \left( \frac{f}{33} \right) \right\} \text{ dB} \quad \text{for } 33 \text{ MHz} \leq f \leq 200 \text{ MHz}$$

where

MDI mode conversion loss( $f$ ) is the MDI mode conversion loss at frequency  $f$   
 $f$  is the frequency in MHz

The below graphs show the IEEE conformance limits for the 100BASE-T1/ 1000BASE-T.



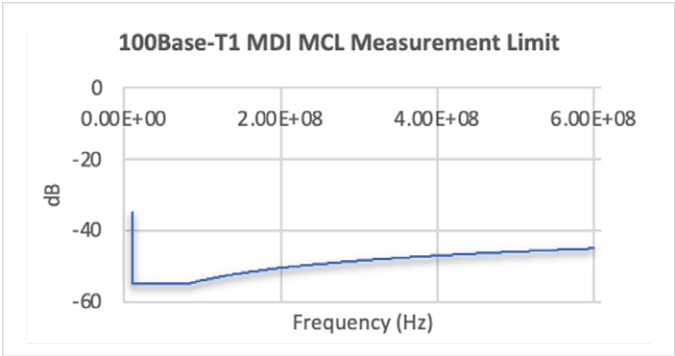
Note: These limit values are defined in IEEE P802.3bw/ D3.3 Standard.

# 1000BASE-T1 MDI Mode Conversion Loss (MCL ) Test Limits

$$\text{ConversionLoss}(f) \geq \begin{cases} 55 & 10 \leq f \leq 80 \\ 77 - 11.51 \log_{10} f & 80 < f \leq 600 \end{cases} \text{ dB}$$

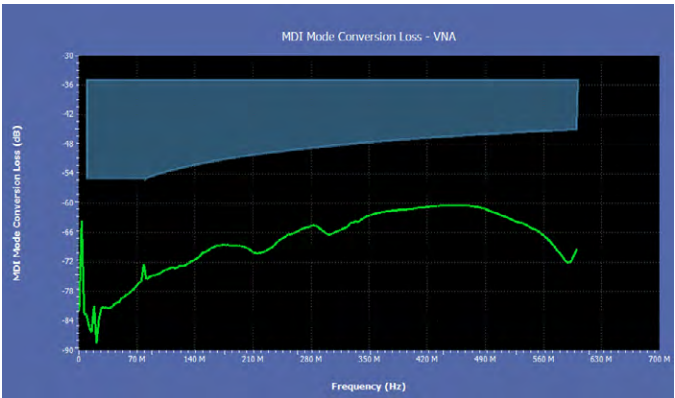
where

$f$  is the frequency in MHz;  $10 \leq f \leq 600$



This limit is from IEEE Std 802.3bp-2016.

Simulation data for the MDI Mode Conversion loss at different ports using a Matnet test fixture.



MDI Mode Conversion TekExpress Plot

## Summary

MDI Mode Conversion Test is performed using an external VNA. This measurement will help to check the compliance of the Common mode EMI/EMC from the ECU-to-ECU (Electronic Control Unit). It is always a challenge for the user to provide a single compliance report. However, the Tektronix automotive compliance solution for 100/1000 Base-T1 provides an option to integrate the external result of MDI Mode Conversion Loss (MCL) to the Tektronix TekExpress report.

**CalPlus GmbH**

Zentrale Berlin  
Heerstraße 32 • 14052 Berlin  
030 214982-0 • Fax: 030 214982-50  
office@calplus.de • www.calplus.de

**CalPlus GmbH**

Niederlassung Hamburg  
Normannenweg 30 • 20537 Hamburg  
040 3039595-0 • Fax: 040 3039595-50  
www.calplus.de

**Contact Information:**

Australia 1 800 709 465  
Austria\* 00800 2255 4835  
Balkans, Israel, South Africa and other ISE Countries +41 52 675 3777  
Belgium\* 00800 2255 4835  
Brazil +55 (11) 3530-8901  
Canada 1 800 833 9200  
Central East Europe / Baltics +41 52 675 3777  
Central Europe / Greece +41 52 675 3777  
Denmark +45 80 88 1401  
Finland +41 52 675 3777  
France\* 00800 2255 4835  
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Japan 81 (3) 6714 3086  
Luxembourg +41 52 675 3777  
Malaysia 1 800 22 55835  
Mexico, Central/South America and Caribbean 52 (55) 88 69 35 25  
Middle East, Asia, and North Africa +41 52 675 3777  
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