Surge Protection Simplified with Intersil's Overvoltage Protected (OVP) Transceivers

## Abstract

This application note presents various protection methods for Intersil's Overvoltage Protected (OVP) transceivers, also known as fault-protected transceivers.

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# Introduction

OVP transceivers have bus I/O stages with high, symmetric stand-off capability of up to ±60V, thus providing protection against high DC potentials and transient voltages within that range (Figure 1).
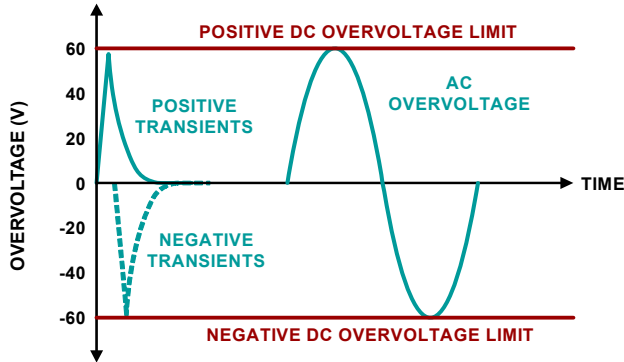


FIGURE 1.  STAND-OFF RANGE OF OVP TRANSCEIVERS

DC faults often occur in applications where 24V DC supply lines share the same conduit with RS-485 data lines. Here sharp cable bends and crunched cables can cause breaks in the cable insulation, thus shorting supply and data lines.

Small transient voltages can result from nearby electronic equipment, inducing switching noise into the bus lines, and from clamping voltages of transient protection components.

The robustness of an OVP transceiver is accomplished with high stand-off voltage transistors and internal current limiting of the driver output stage. Since Intersil's OVP transceivers also support a wide Common-Mode Voltage Range (CMVR) of up to ±25V, the current limiter has a dual fold-back characteristic (Figure 2).
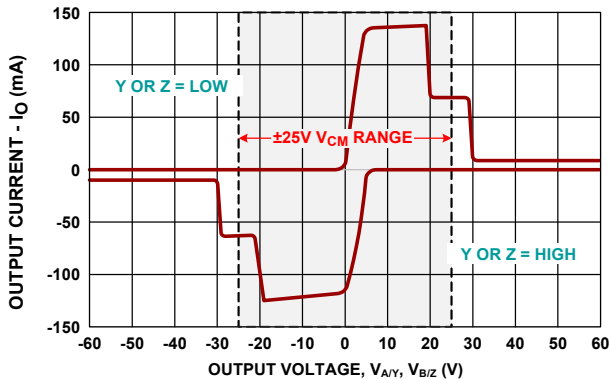


FIGURE 2.  DUAL FOLDBACK CHARACTERISTIC OF CURRENT LIMITER

Dual foldback current limiting limits the power consumption of an active driver during a fault event, while enabling the driver to maintain operation across the wide CMVR.

In order to prevent the transceiver on-chip ESD protection from interfering with an external transient suppressor, the SCR trigger

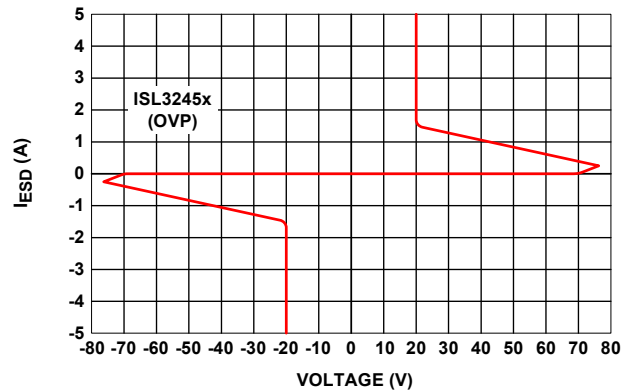voltage of an OVP transceiver lies far outside the ±60V operating range (Figure 3).



FIGURE 3.  V-I CHARACTERISTIC OF AN OVP TRANSCEIVER'S ESD PROTECTION CIRCUIT

The symmetric protection range of an OVP transceiver is a major benefit for surge protection designs as it relieves designers from being limited to the one asymmetric clamping TVS device available on the market.

Designers can chose from a vast range of symmetrically clamping TVS devices with higher current capability and lower junction capacitance than the SM712.

# Design Examples

The following transient protection schemes differ in CMVR, protection level, line-to-ground (common-mode) capacitance, and required board space.

While aiming for a high level of protection is important, another goal of transient protection design is keeping TVS capacitance as low as possible to minimize bus loading.

For applications with reduced CMVR, this is easily accomplished using low-capacitance TVS devices with small form factors that also consume less board space.

Applications with extended CMVR (such as ±25V) require components with high working voltages. Single protection devices with a high working voltage can have large junction capacitances, thus making them less attractive for consideration.

To reduce overall capacitance, a low-capacitance device can be connected in series with a high-capacitance device. The trade-off is a slight increase in board space.

Easing the assessment of how much data rate a protection scheme can support, Semtech's application team created a TVS capacitance versus data rate characteristic, shown as the green, single bus node line in Figure 4  on page 3.
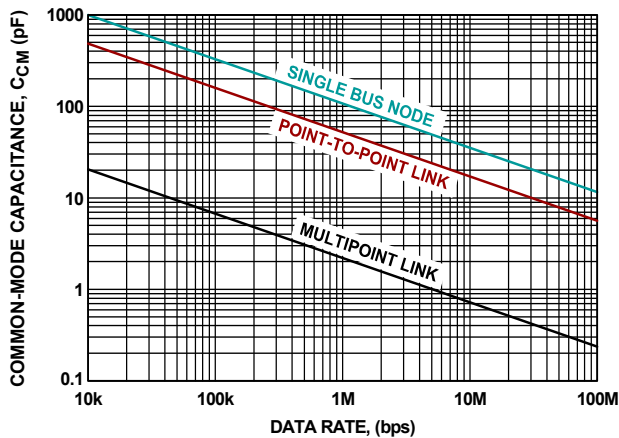
FIGURE 4. COMMON-MODE CAPACITANCE OVER DATA RATE

For any given data rate, the TVS capacitance, aka line-to-ground or common-mode capacitance, drops with an increase in bus nodes. While this characteristic does not include the connector and cable capacitances, it provides a good approximation of the maximum allowed capacitance of a protection scheme.

To quickly assess a circuit's maximum protection level and thus $V_{PK}$, use the simplified equivalent circuit of the surge test setup in Figure 5.
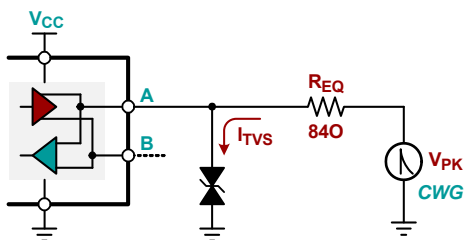


FIGURE 5. SURGE TEST EQUIVALENT CIRCUIT

Here, $R_{EQ}$ is the equivalent source resistance of the surge generator of 84Ω. $I_{TVS}$ is the TVS peak pulse current, derated for the transceiver's maximum operating temperature of +85°C:

$$I_{TVS} = I_{PP} \bullet DF \qquad \text{(EQ. 1)}$$

$I_{PP}$ is the TVS peak pulse current specified at +25°C, and DF is the temperature derating factor. The peak generator voltage can thus be calculated with:

$$V_{PK} = I_{PP} \bullet DF \bullet R_{EQ} \qquad \text{(EQ. 2)}$$

While TVS datasheets often show derating curves for average power values, the derating factors for short pulses, such as the 8/20µs pulse, can be significantly higher. For example, the TVS diodes presented in this paper have an average power derating of 50% at +85°C, while their actual pulse-power derating is 80%.

All following calculations therefore use an 80% derating, or DF = 0.8. Inserting the values for DF and $R_{EQ}$ simplifies Equation 2:

$$V_{PK} = I_{PP} \bullet 67.2\Omega \qquad \text{(EQ. 3)}$$

## Protection Scheme 1

The protection circuits in Figures 6 and 7 apply to data links without negative CMVR. Typical applications are Endat2.0 interfaces in shaft encoders of motor control systems. The Endat2.0 interface is a point-to-point link. Its interface cable of 300m maximum length includes DC power lines and RS-485 data lines. The DC ground line connects the local driver ground with the remote receiver ground, thus eliminating ground potential differences, while enabling the use of unidirectional, low-capacitance TVS diodes.

The circuit in Figure 6 presents a special case in our OVP discussion, as it uses a 100Mbps, standard transceiver. This example shows that applications with a unipolar common-mode range can use a standard transceiver and still be protected against IEC61000-4-5, Level 1 surge transients, if the correct protection device is selected. This is of particular importance as OVP transceivers with 100Mbps capability do not exist.
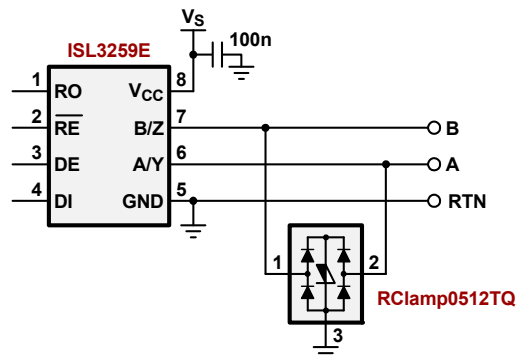


FIGURE 6. RClamp0512TQ TVS FOR UNIDIRECTIONAL
TRANSIENT PROTECTING AGAINST 10A SURGE
CURRENT PER LINE

To prevent the transceiver internal ESD from interfering with the switching characteristic of the external TVS, a thyristor device with snapback characteristic was chosen, whose breakover and clamping voltages are below the trigger threshold of the transceiver's ESD circuitry (Figure 7 on page 4).

The RClamp0512TQ is a 3pF, low-capacitance device with 5V stand-off ($V_{RWM}$), thus satisfying the 5V CMVR requirement. Its rated peak pulse current of 10A (8/20µs) per data line generates a clamping voltage of about 4V. Using Equation 3, the maximum protection level, $V_{PK}$, is calculated, yielding:

$V_{PK}$ = 10A x 67.2Ω = 672V

This voltage exceeds the IEC61000-4-5, protection Level 1 of 500V. Also, the device line-to-ground capacitance of 3pF is well below the maximum value of 6pF suggested for a 100Mbps point-to-point link in Figure 4 on page 3.

Figure 7 shows the TVS V-I characteristic in comparison with the 5V CMVR and the 15V ESD trigger threshold of the ISL3259 transceiver.
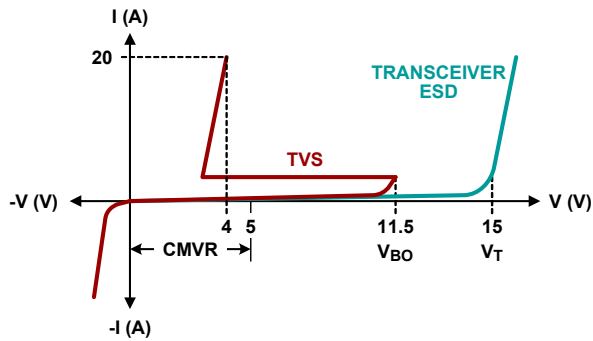
FIGURE 7. V-I CHARACTERISTIC OF RClamp0512TQ

## Protection Scheme 2

Higher protection levels of applications with 5V CMVR demand more robust protection devices whose clamping voltages exceed the stand-off voltage range of standard transceivers. The circuit in Figure 8 therefore uses the 20Mbps OVP transceiver, ISL32458E, in combination with Semtech's TClamp1202P.

The TClamp1202P is probably the most powerful and universal, 12V TVS on the market. The center TVS element has a working voltage of 12V and is rated for a peak pulse current of 100A. The device can be operated in unidirectional or bidirectional mode. In unidirectional mode, the device protects two data lines against surge currents of up to 50A each, while reaching a maximum clamping voltage of 40V. In this mode, its line-to-ground capacitance is 12pF, thus matching the recommended maximum for a 20Mbps, point-to-point link. Most impressive however, are the device's small package dimensions of 2mm x 2mm.


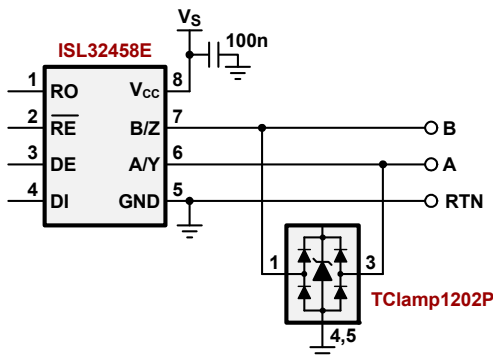
FIGURE 8. TClamp1202P TVS IN UNIDIRECTIONAL MODE PROTECTING AGAINST 50A SURGE CURRENT PER LINE

The circuit's maximum protection level is:

$V_{PK}$ = 50A x 67.2Ω = 3360V, thus exceeding the IEC61000-4-5, protection Level 3 of 2000V.

## Protection Scheme 3

The protection scheme in Figure 9 protects a bus node over a ±12V CMVR, slightly wider than the RS-485 standard common-mode range of -7V to 12V.

Here, the TClamp1202P is configured for bidirectional operation, protecting a single line. Its peak pulse current capability therefore increases to 100A, while its line-to-ground capacitance is reduced down to 6pF. Due to the additional diode drop in

bidirectional mode, the maximum clamping voltage is 52V, which is well below the transceiver stand-off voltage of 60V.
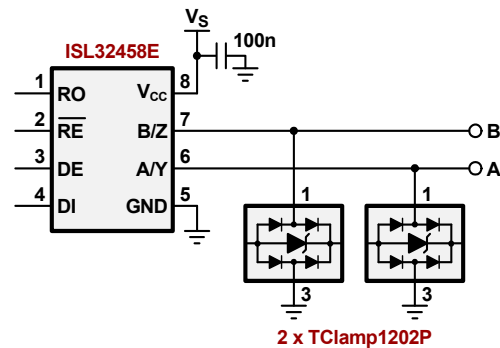


FIGURE 9. TWO TClamp1202P DEVICES IN BIDIRECTIONAL MODE PROTECTING AGAINST 100A SURGE CURRENT OVER ±12V CMVR

The scheme's maximum protection level is:

$V_{PK}$ = 100A x 67.2Ω = 6.72kV, reaching Level X in the IEC61000-4-5 scale of protection levels.

## Protection Scheme 4

This protection scheme protects bus nodes over the extended CMVR of ±20V.
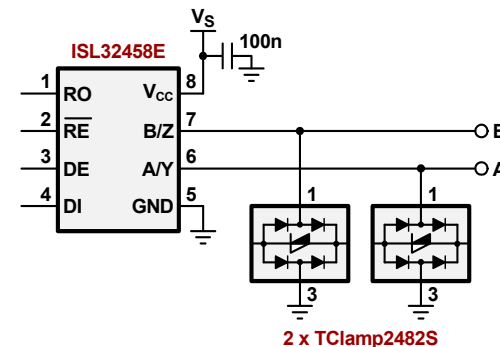


FIGURE 10. TWO TClamp2482S DEVICES IN BIDIRECTIONAL MODE PROTECTING AGAINST 30A SURGE CURRENT OVER ±20V CMVR

The TClamp2482S has a snapback characteristic with a maximum $V_{BO}$ of 35V and a typical $V_C$ of 7.5V at 30A $I_{PP}$. Its maximum line-to-ground capacitance is an impressively low 1.8pF. The circuit's maximum protection level is:

$V_{PK}$ = 30A x 67.2Ω = 2016V, providing IEC61000-4-5 Level 3 (2kV) surge protection.

## Protection Scheme 5

In industrial automation, the 24V DC supply for analog and digital modules is commonly distributed through the same conduits as the RS-485 data lines. This introduces the risk of short-circuits between supply and data conductors in the case of insulation faults. The duration of these faults can last for minutes and days until their causes are eliminated.

To prevent TVS burnout due to a DC fault, its breakdown threshold must be higher than the maximum possible DC voltage. Since 24V supplies can experience excursion of up to

30V, transient protection schemes of RS-485 bus nodes must provide working voltages higher than that. At the same time, the maximum clamping voltage of the protection circuit must remain below the transceiver stand-off voltage of 60V. The protection scheme in Figure 11 accomplishes both requirements by connecting a TVS (TClamp1202P) in series with a thyristor (TClamp2482S) to protect a single line.



FIGURE 11. TClamp1202P AND TClamp2482S PROTECTING EACH LINE AGAINST 30A SURGE CURRENT OVER ±36V VOLTAGE RANGE

While it is easy to find device combinations that achieve the required working voltage, care must be applied that the sum of the TVS breakdown and the thyristor breakover voltage remain below the transceiver stand-off.
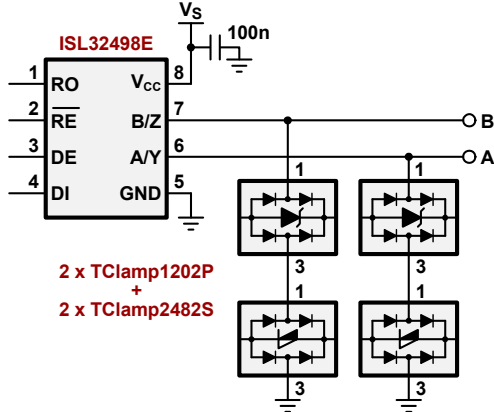
In the clamping region then, the TVS voltage continues to increase linearly with rising current, while the thyristor snaps back to a low-voltage level, which remains nearly constant up to the rated peak pulse current.

Figure 12 shows the individual and combined V-I characteristics of the protection scheme. Here the combined, maximum clamping voltage is 38.5V.

While the TVS is able to conduct currents of up to 100A, the thyristor's rated peak pulse current of 30A represents the current limit of the combined solution. The maximum applicable surge test voltage is therefore:

$V_{PK}$ = 30A x 67.2Ω = 2016V, attaining IEC61000-4-5 Level 3 (2kV) surge protection.

The circuit's line-to-ground capacitance is made up by the 6pF between the data ports of the TClamp1202P in series with the 1.8pF between the data ports of the TClamp2482S, resulting in a total of 1.4pF.
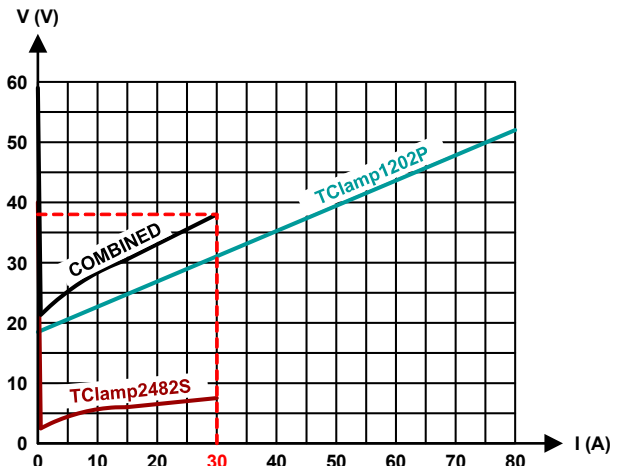


FIGURE 12. V-I CHARACTERISTICS OF PROTECTION SCHEME 5

## Protection Scheme 6

To accomplish higher levels of protection, the circuit in Figure 13 uses thyristors with much higher current ratings.
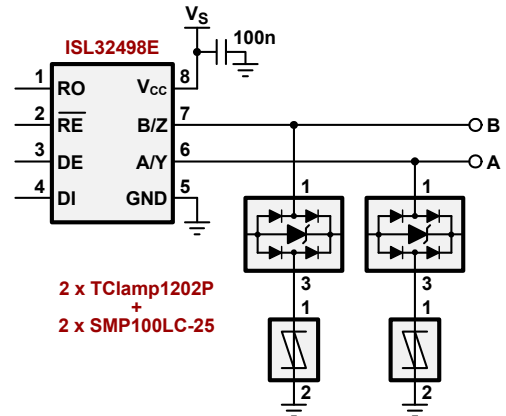


FIGURE 13. TClamp1202P AND SMP100LC-25 PROTECTING EACH LINE AGAINST 95A SURGE CURRENT OVER ±31V VOLTAGE RANGE

Here, the 400A (8/20µs) rated peak pulse current of the SMP100LC-25 supports the high current capability of the TClamp1202P, thus yielding a protection level of:

$V_{PK}$ = 100A x 67.2Ω = 6.72kV

This represents Level X in the IEC61000-4-5 scale of protection levels.

Again, the low capacitance of the TClamp1202P in series with the 65pF of the SMP100LC-25 assures a low line-to-ground capacitance of only 5.5pF. Figure 14 on page 6 shows the V-I characteristics of the solution, depicting a maximum clamping voltage of 56V at the derated current of 80A.

FIGURE 14. V-I CHARACTERISTICS OF PROTECTION SCHEME 6

## Conclusion

Intersil OVP transceivers in combination with Semtech transient protection devices enable the fast and easy design of highly efficient protection circuits against ESD, EFT and surge transients.

The protection schemes presented in this application note are summarized in Table 1.

All of these designs provide higher protection levels, higher reliability, lower capacitance and smaller board space than protection schemes using standard transceivers with MOVs, PTCs and GDTs, all of which have wear-out mechanisms and are subject to premature component failure.

Intersil's OVP transceiver portfolio is listed in Table 2.

### TABLE 1. PERFORMANCE SUMMARY OF PROTECTION SCHEMES

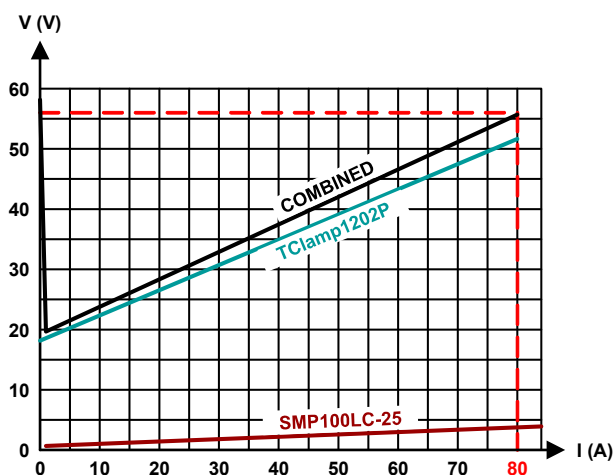| PROTECTION SCHEME | PROTECTION | | STAND-OFF VOLTAGE (V) | LINE-GROUND CAPACITANCE (pF) | BOARD SPACE (mm$^2$) | TRANSCEIVER FAMILY | PROTECTION DEVICES | MANUFACTURER |
| | LEVEL | VOLTAGE (kV) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 0.7 | 5 | 3 | 0.6 | ISL3259E | RCLAMP0512TQ | SEMTECH |
| 2 | 3 | 3.2 | 12 | 12 | 4 | ISL3245xE | TCLAMP1202P | SEMTECH |
| 3 | X | 6.7 | ±12 | 6 | 8 | | 2 x TCLAMP1202P | SEMTECH |
| 4 | 3 | 2.0 | ±24 | 1.8 | 16 | | TCLAMP2482S | SEMTECH |
| 5 | 3 | 2.0 | ±36 | 1.4 | 24 | ISL3249xE | 2 x TCLAMP1202P + 2 x TCLAMP2482S | SEMTECH |
| 6 | X | 6.7 | ±34 | 5.5 | 47 | | 2 x TCLAMP1202P + 2 x SMP100LC-25 | SEMTECH STM |

### TABLE 2. INTERSIL OVP TRANSCEIVER PORTFOLIO

| DEVICE | OVP (V) | CMVR (V) | DATA RATE (MBPS) | HALF/FULL DUPLEX | HOT PLUG | PACKAGE |
|---|---|---|---|---|---|---|
| OVP TRANSCEIVERS WITH 3V TO 5V SUPPLY | | | | | | |
| ISL32430E | ±40 | ±15 | 0.25 | Full | No | MSOP10, SOIC14 |
| ISL32432E | ±40 | ±15 | 0.25 | Half | No | MSOP8, SOIC8 |
| ISL32433E | ±40 | ±15 | 1 | Full | No | MSOP10, SOIC14 |
| ISL32435E | ±40 | ±15 | 1 | Half | No | MSOP8, SOIC8 |
| ISL32450E | ±60 | ±20 | 0.25 | Full | No | MSOP10, SOIC14 |
| ISL32452E | ±60 | ±20 | 0.25 | Half | No | MSOP8, SOIC8 |
| ISL32453E | ±60 | ±20 | 1 | Full | No | MSOP10, SOIC14 |
| ISL32455E | ±60 | ±20 | 1 | Half | No | MSOP8, SOIC8 |
| ISL32458E | ±60 | ±20 | 20 | Half | No | SOIC8 |

**TABLE 2. INTERSIL OVP TRANSCEIVER PORTFOLIO (Continued)**

| DEVICE | OVP (V) | CMVR (V) | DATA RATE (MBPS) | HALF/FULL DUPLEX | HOT PLUG | PACKAGE |
|---|---|---|---|---|---|---|
| **OVP TRANSCEIVERS WITH 5V SUPPLY AND HOT-PLUG CAPABILITY** | | | | | | |
| ISL32470E | ±60 | ±15 | 0.25 | Full | Yes | SOIC14 |
| ISL32472E | ±60 | ±15 | 0.25 | Half | Yes | SOIC8 |
| ISL32475E | ±60 | ±15 | 1 | Half | Yes | SOIC8 |
| ISL32478E | ±60 | ±15 | 15 | Half | Yes | SOIC8 |
| ISL32490E | ±60 | ±25 | 0.25 | Full | Yes | MSOP10, SOIC14 |
| ISL32492E | ±60 | ±25 | 0.25 | Half | Yes | MSOP8, SOIC8 |
| ISL32493E | ±60 | ±25 | 1 | Full | Yes | MSOP10, SOIC14 |
| ISL32495E | ±60 | ±25 | 1 | Half | Yes | MSOP8, SOIC8 |
| ISL32496E | ±60 | ±25 | 15 | Full | Yes | MSOP10, SOIC14 |
| ISL32498E | ±60 | ±25 | 15 | Half | Yes | MSOP8, SOIC8 |
| **OVP TRANSCEIVERS WITH CABLE-INVERT FUNCTION** | | | | | | |
| ISL32437E (3V - 5V) | ±40 | ±15 | 0.25 | Half | No | MSOP8, SOIC8 |
| ISL32457E (3V - 5V) | ±60 | ±20 | 0.25 | Half | No | MSOP8, SOIC8 |
| ISL32459E (5V) | ±60 | ±20 | 20 | Half | No | SOIC8 |
| ISL32483E (5V) | ±60 | ±25 | 1 | Full | Yes | SOIC14 |
| ISL32485E (5V) | ±60 | ±25 | 1 | Half | Yes | SOIC8 |

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