Application Note 324
T1/E1 Network Interface Design

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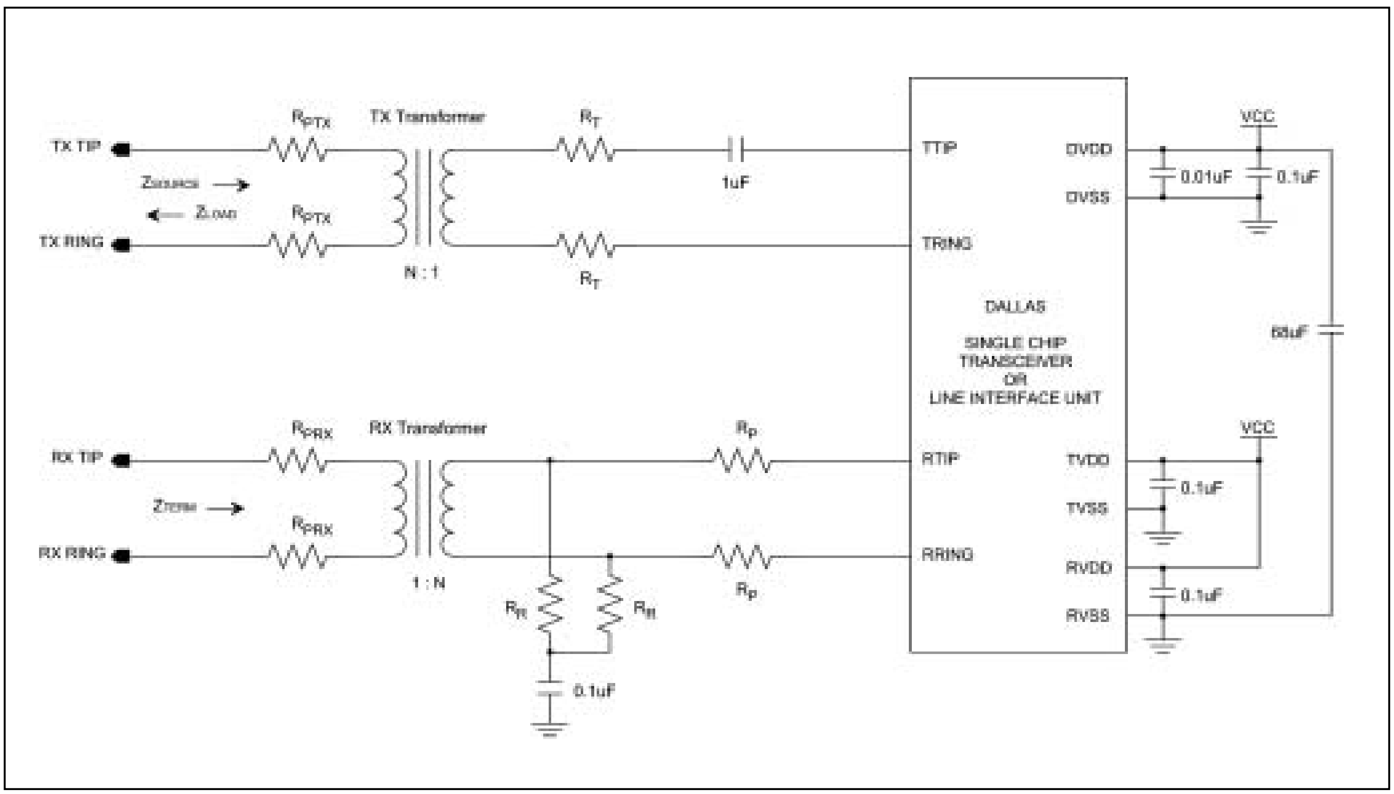
INTRODUCTION

Figure 1 illustrates a general interface for T1/E1 transceiver chips. The circuit is an unprotected network interface and shows a general idea about how to distribute resistance around the transformers. When designing the network interface for specific applications, more or fewer components may be necessary. One example is an over voltage protection network. For this application, it is necessary to add voltage suppression- and current-limiting devices. This type of design is discussed in more detail later in this application note.

The following paragraph is a brief overview of the line interface for the Dallas Semiconductor T1 and E1 parts. The transmitter output drivers present a low impedance to inbound surges and must be able to drive sufficient current into the primary winding of the transmit transformer in order to produce the required output pulse. The transmitter outputs are designed to fit an output pulse into a template using a step-up transformer under a matched load with 0Ω of inline resistance. The step-up transformer is based on the supply voltage and the matched load depends on the line impedance—100Ω for T1 and 75Ω or 120Ω for E1. The receiver inputs present a high impedance to inbound surges and requires very little input current to operate. The receiver inputs are designed to recover a signal using a 1:1 transformer with 0Ω of series resistance under a matched load. For these reasons, the transmitter and receiver pins require different protection techniques.

Figure 1. General Network Interface Circuit



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RECEIVE CIRCUIT

The receive circuit is the most straight forward. Generally a 1:1 transformer is used to interface to the receiver inputs. The primary consideration in the receive circuit is the accurate termination of the transmission line. A T1 signal is carried on 100Ω balanced twisted pair while an E1 signal is carried on either 75Ω unbalanced coax or 120Ω balanced twisted pair. The components involved in the termination network are the R_R, and R_{PRX} resistors. The ideal termination circuit would be if the R_{PRX} resistors were 0Ω and the resistance of R_R equaled half of the characteristic line impedance. Since the R_{PRX} resistors may be necessary as part of a protection network, they form a voltage divider and R_R must be adjusted. As the resistance of the R_{PRX} resistors increases, the resistance of R_R decreases. If the R_{PRX} resistors become too large, then the receiver may be unable to recover weak signals. The following equation describes the termination:

$$Z_{term} = R_{PRX} + R_{PRX} + 2\ R_R / N^2$$

Substitute: Z_{term} = 100Ω (T1) or 75Ω, 120Ω (E1) and N = 1

Then solve for R_{PRX} and R_R

The R_P resistors in the circuit are for current limiting purposes and do not significantly affect the termination due to the high impedance of the receiver inputs. Capacitor C_1, along with resistors R_R, form a high frequency cutoff filter for improved noise immunity.

INTERNAL RECEIVE TERMINATION

To ease the design of receive termination for both T1 and E1 circuits, Dallas Semiconductor has designed the ability to select the termination using software into the DS2148 and DS2155. By designing the receive circuit for 120Ω termination, the internal line interface unit can selectively add resistance to the line to achieve termination settings of 75Ω, 100Ω or 120Ω. When using internal termination two changes must be made to the external components. First, the Rr resistors must be 60Ω (this sets up a line termination of 120Ω) and the Rp resistors must be omitted from the circuit. Omitting the Rp resistors is necessary because the 470Ω resistors would interfere with the additional resistance that the internal circuitry adds. Second, the R_{PRX} resistors must be omitted for the internal termination to match the impedance properly. If these resistors are present, the received signal will be degraded by the resulting impedance mismatch in line termination. If the receive circuitry needs to be protected, voltage suppression must be used. This is discussed later in the application note.

TRANSMIT CIRCUIT

Since the signal pulses for T1 and E1 are different and the source voltage for the driver can be either 3.3V or 5.0V, the transmit circuit description is more complicated than the receive circuit. When designing the transmit circuit, several considerations must be taken into account. Some applications require that the source impedance be closely matched to the characteristic impedance of the network. Along with this there may be a need to provide for protection of the circuit against power line cross (UL) and transient (FCC) conditions.

The following is a description of the transmitter interface for both T1 and E1 networks. The circuit in Figure 1 is a basic network circuit and does not provide protection. Circuits designed with diodes, fuses, and voltage suppressors are more universal with an improved level of protection. For this reason, these descriptions are for reference only. Protected network interfaces are discussed later in more detail.

T1 DEVICE TRANSMIT CIRCUIT

The transmitter outputs of Dallas Semiconductor T1 parts are designed to generate the correct pulse amplitude at the network interface for varying line lengths. Since the different line lengths affect the pulse shape, the parts have programmable output levels. Every part has a transmitter LBO table in the data sheet, which shows the settings to choose based on the transformer turn ratio and the line length. A default T1 pulse for a known line length is generated under the following conditions: 5.0V supply, $R_{PTX} = R_T = 0Ω$, and the Tx transformer has a turn ratio of 1:1.15. For circuits requiring protection the value of the resistors may be increased. However, as series resistance is increased, so is signal attenuation and a transformer with a larger turn ratio must be selected to compensate for the loss.

A nominal 0dB T1 pulse is 3V under a 100Ω load or 3V at 30mA on the network interface. An unprotected circuit using a 1:1.15 transformer with series resistance of 0Ω, will have to produce a 3V × 1/1.15 = 2.6V pulse at the output pins of the device. The current drive into the primary winding of the tansformer will be 30mA × 1.15 = 34mA. If resistors R_{PTX} or R_T are added to protect the device from surges, a 1:1.36 transformer will be necessary. While the current pulse in the secondary loop of the 1:1.36 transformer will remain the same, the current pulse in the primary of the transformer will be 30mA × 1.36 = 40mA. Because the output voltage pulse is still 2.6V, the net impedance (R_L) seen by the transmitter will be 2.6V / 40mA = 65Ω and is described by:

$$R_L = Z_{LOAD} / N^2 + R_{PTX} / N^2 + R_{PTX} / N^2 + 2\ R_T$$

$$\text{Substitute: } R_L = 65\Omega,\ Z_{LOAD} = 100\Omega, \text{ and } N = 1.36$$

$$65\Omega = 100\Omega / 1.36^2 + (R_{PTX} + R_{PTX}) / 1.36^2 + 2\ R_T$$

$$\text{Simplify: } 10.9\Omega = (R_{PTX} + R_{PTX}) / 1.85 + 2\ R_T$$

If the R_{PTX} resistors are 0Ω then R_T = 5.5Ω. Since 4.7Ω is the closest standard value that is less than the theoretical limit, it can be used in the circuit. If R_T is 0Ω then the R_{PTX} resistors can be as much as 10Ω each and will also provide current limit protection for the transformer. In this circuit, the R_{PTX} resistors can be combined into a single component on the network side of the transformer. Any resistance that is on the line side must be divided equally in the TIP and RING output circuits so that the line is balanced.

Devices operating from a 3.3V supply require a 1:2 step up transformer to produce a sufficient voltage pulse on the transformer secondary. In order to produce the required 3V pulse under a 100Ω load, a current pulse of 30mA × 2 = 60mA is required from the transmitter output drivers. Adding series resistance to this network would require a turn ratio greater than 1:2 and thus even larger currents from the transmitter. For this reason, it is recommended that 3.3V circuits be designed with 0Ω of series resistance and use other components for over voltage protection. Schottky diodes placed in a bridge configuration connected to TTIP and TRING will turn on sooner than the silicon diodes in the transmit output drivers and conduct energy away from the CMOS device. The use of Schottky diodes and fuses as protection methods for both 3.3V and 5.0V designs is discussed later.

E1 DEVICE TRANSMIT CIRCUIT

The transmitter outputs of Dallas Semiconductor E1 parts are designed to generate the correct pulse at the network interface under varying termination conditions. The parts have programmable output levels which along with the transmit transformer are used to compensate for resistive components between TTIP and TRING and the network interface. This ensures that signals arrive at the network interface with a peak voltage of 3.0V for 120Ω applications or 2.37V for 75Ω applications. Unlike in T1, E1 applications can have additional resistance in the transmit path that matches the source impedance to the characteristic line impedance. This extra resistance results in a further reduction in signal reflections and line noise being coupled into the transmitter outputs. Return Loss is a measure of how well the source and line impedance are matched. A higher return loss results in more attenuation of any noise or reflected signals and is calculated by:

$$\text{Return Loss (dB)} = 20 \log_{10} |Z_{SOURCE} + Z_{LOAD}| / |Z_{SOURCE} - Z_{LOAD}|$$

$$\text{Where: } Z_{LOAD} = 120\Omega \text{ or } 75\Omega$$

$$\text{and } Z_{SOURCE} = R_{PTX} + R_{PTX} + (2\ R_T + 5) \times N^2$$

The constant of 5 in the Z_{SOURCE} equation above is the internal impedance of the transmitter. The return loss for an unprotected network interface without a high return loss condition is shown below. In the example resistors the supply voltage is 5.0V, R_1 & R_2 & Rt = 0Ω, the Tx transformer has a turn ratio of 1:1.15, and the line impedance is 75Ω.

$$\text{Return Loss (dB)} = 20 \log_{10} |Z_{SOURCE} + Z_{LOAD}| / |Z_{SOURCE} - Z_{LOAD}|$$

$$\text{Substitute: } Z_{load} = 75\Omega,\ N = 1.15, \text{ and } R_{PTX}\ \&\ R_T = 0\Omega$$

$$\text{Return Loss} = 20 \log_{10} |5 \times 1.15^2 + 75| / |5 \times 1.15^2 - 75|$$

$$\text{Return Loss} = 20 \log_{10} 1.21$$

$$\text{Return Loss} = 1.5 \text{ dB}$$

In this example, 83% of the noise or reflected signal can be coupled into the transmitter outputs. To improve the return loss, the value of Rt can be increased. Changing R_T to a value of 27Ω increases the return loss to 34dB. This means less than 2% of the inbound signal will be reflected.

When changing the value of the R_{PTX} or R_T resistors it is important to note that there will be changes in the output pulse amplitude. When designing with Dallas Semiconductor E1 parts, consult the LBO table in the data sheet for proper transformer and resistor selection. Each setting is based on the operational voltage, the transformer turn ratio, and R_T. The LBO tables from the DS21554 and DS21354 data sheets are shown in Table 1 and Table 2, respectively.

Table 1. LBO Select in LICR for 5V Devices

L2	L1	L0	APPLICATION	TRANSMIT TRANSFORMER	RETURN LOSS[1]	R_T [2]
0	0	0	75Ω normal	1:1.15 stepup		0
0	0	1	120Ω normal	1:1.15 stepup		0
0	1	0	75Ω normal with protection resistors	1:1.15 stepup		8.2
0	1	1	120Ω normal with protection resistors	1:1.15 stepup		8.2
1	0	0	75Ω with high return loss	1:1.15 stepup	> 21dB	27
1	1	0	75Ω with high return loss	1:1.36 stepup	> 21dB	18
1	0	0	120Ω with high return loss	1:1.36 stepup	> 21dB	27

Table 2. LBO Select in LICR for 3.3V Devices

L2	L1	L0	APPLICATION	TRANSMIT TRANSFORMER	RETURN LOSS[1]	R_T [2]
0	0	0	75Ω normal	1:2 stepup		0
0	0	1	120Ω normal	1:2 stepup		0
0	1	0	75Ω normal with protection resistors	1:2 stepup		2.5
0	1	1	120Ω normal with protection resistors	1:2 stepup		2.5
1	0	0	75Ω with high return loss	1:2 stepup	> 21dB	6.2
1	0	1	120Ω with high return loss	1:2 stepup	> 21dB	11.6

Note 1: Empty cells indicate that the return loss is less than 21dB.
Note 2: The value of R_T shown assumes that both R_{PTX} resistors = 0Ω.

INTERNAL TRANSMIT TERMINATION

To ease the design of transmit termination for E1 circuits and include T1 transmit termination, Dallas Semiconductor has designed the ability to select the termination using software into the DS2155. By designing the transmit circuit with 0Ω of inline resistance, the transmit interface unit can selectively add inline resistance to match the transmitter impedance to a 75Ω, 100Ω or 120Ω line. When using internal termination two changes must be made to the external components. First, the R_T resistors must be 0Ω. Second, the R_{PTX} protection resistors must be omitted for the internal termination to match the impedance properly. If these resistors are present, the transmit signal will be degraded by the resulting impedance mismatch in line termination. If the transmit circuitry needs to be protected, voltage suppression should be used. This is discussed later in the application note.

INTRODUCTION TO PROTECTION CIRCUITS

Dallas Semiconductor single-chip transceivers (SCTs) and line interface units (LIUs) are used in applications connecting directly to the outgoing telephone lines which can expose the devices to hazardous overvoltage conditions. For such applications, protection networks must be used to direct high voltages or currents away from the sensitive low-voltage CMOS devices. Protection networks are divided into two catagories, primary and secondary voltage protection. Primary voltage protection is usually provided by gas discharge tubes or carbon block located at the point where the line enters the premises. Since the primary voltage protection only limits the voltage surges to $1000V_{PEAK}$ and power line cross to 600V (RMS), secondary voltage protection is necessary. The secondary voltage protection provides additional voltage and current limiting so the network interface device is not damaged. Longitudinal (common mode) surge types are from Tip to Ground or Ring to Ground while Metallic (differential) surge types are between Tip and Ring. Longitudinal surges are formed on the Tip and Ring conductors by lightning currents that enter the conductive shield of the cable. Metallic surges are a byproduct of longitudinal surges and are formed between the Tip and Ring conductors by imbalances in the the operation of the primary protectors or equipment on the line. The following secondary voltage protection examples provide immunity from metallic and longitudinal surges as well as for power-line cross. These circuit designs are targeted for compliance with one or more standard including but not limited to:

Underwriters Laboratories UL 60950 (formerly UL 1950)
Telecommunications Industry Association TIA/EIA-IS-968 (formerly FCC Part 68)
Telcordia (formerly Bellcore) GR 1089-Core
International Telecommunication Union ITU-T K.20, K.21

VOLTAGE SUPPRESSION PROTECTION CIRCUITS

To meet the increasing demands placed on the telecommunications industry, traditional components such as Metal Oxide Varistors and Power Resistors must be replaced. The designs in Figure 2 and Figure 3 have three major advantages. They decrease the amount of surface area used by components. All of the components used in the design are surface mount for ease of assembly. Finally, they allow for low voltage operation while maintaining the same level of protection offered by traditional circuits. Figure 2 is an example of a metallic surge suppression circuit while Figure 3 is an example of a longitudinal surge suppression circuit.

The two main components used for protection are the fuse and thyristor devices. The thyristor is a solid state crow-bar device that changes from an open circuit to a short circuit condition when the voltage across the device exceeds the switching voltage. The thyristor will remain in the short circuit state until the current flowing through the device falls below a set holding current. In the short circuit state, excess current is routed between the two transmission lines thus stopping it from damaging the semiconductor device. The fuse protects the transformer against high current conditions such as power line cross. The current rating of the fuse is set to match the maximum power dissipation of the transformer. (Note: A fuse typically breaks at 135% of its current rating.) Typical fuses have a surge current rating above 50A for the different voltage and current surge models. If the surge current rating is less than 100A, a current-limiting series resistor will be necessary. There are a couple of fuses currently on the market which pass the 2 x 10µs, 10 x 160µs, 10 x 560µs, and 10 x 1000µs, surges and do not require current limiting resistors. The following designs take advantage of these fuses along with thyristor devices.

Figure 2. Voltage Suppression, Metallic Protection

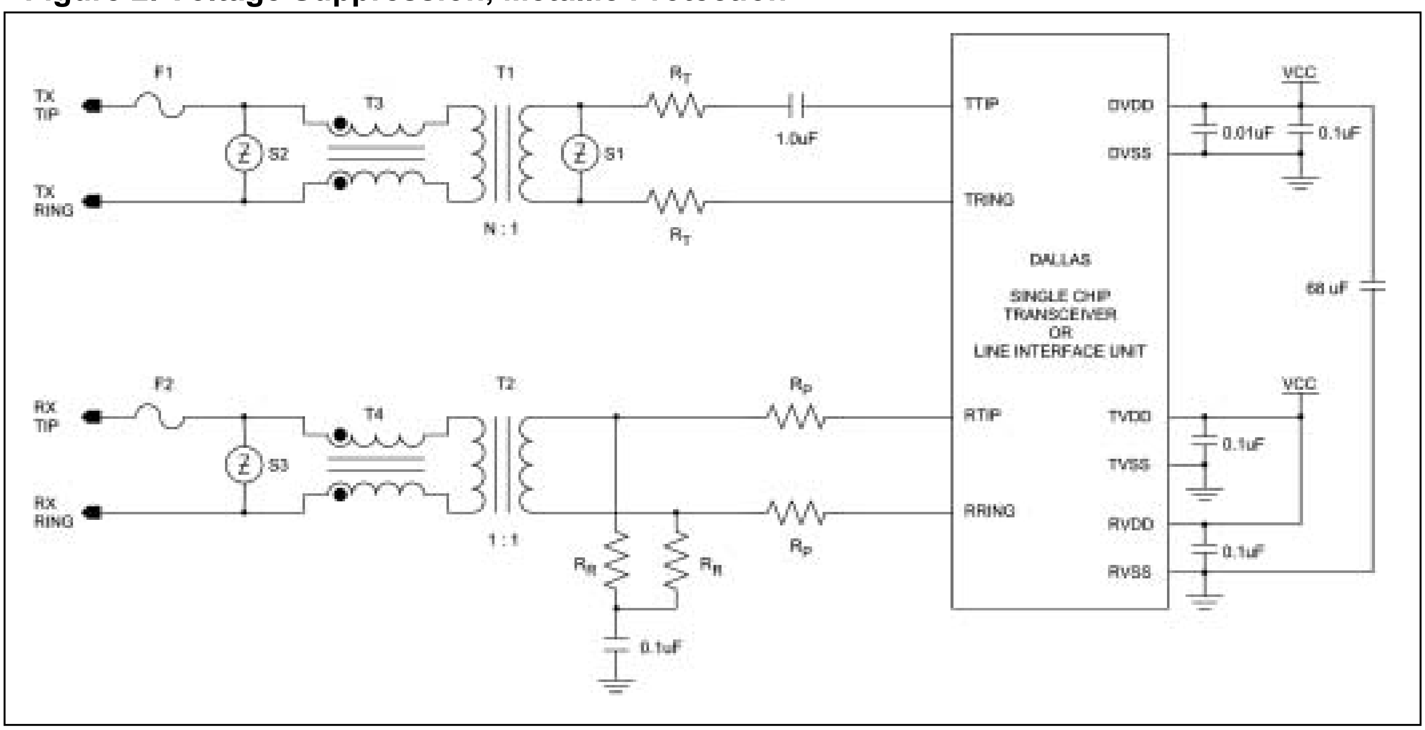

Table 3. Component List Voltage Suppression, Metallic Protection)

NAME		DESCRIPTION	PART	MANUFACTURER
F1, F2		1.25A Slow Blow Fuse	SMP 1.25	Bel Fuse
		1.25A Slow Blow Fuse	F1250T	Teccor Electronics
R_P		475Ω 1%, 1/8W	CRCW 1206 475R F	Vishay
R_R	T1	50Ω 1%, 1/8W	CRCW 1206 49R9 F	Vishay
	E1 75Ω	37.5Ω 1%, 1/8W	CRCW 1206 37R4 F	Vishay
	E1 120Ω	60Ω 1%, 1/8W	CRCW 1206 60R4 F	Vishay
R_T		Transmit Resistor (1%, 1/8W) (Note 1)	—	Vishay
S1		25V (max) Transient Suppressor	P0080SA MC	Teccor Electronics
S2, S3		77V (nax) Transient Suppressor	P0640SC MC	Teccor Electronics
T1 and T2		Transformer 1:1CT and 1:136CT (5.0V, SMT) (Note 2)	T1136	Pulse Engineering
T1 and T2		Transformer 1:1CT and 1:2CT (3.3V, SMT) (Note 2)	PE-68678	Pulse Engineering
T3 and T4		Dual Common-Mode Choke (SMT)	PE-65857	Pulse Engineering

Note 1: The value of Rt is application dependent. Use the Dallas Semiconductor device data sheet for more information.
Note 2: Alternate transformer part numbers and manufacturers are located at the end of this application note.
Note 3: The layout from the transformers to the network interface is critical. Traces should be at least 25 mils wide and separated from other circuit lines by at least 150 mils. The area under this portion of the circuit should not contain power planes.
Note 4: Some T1 (never E1) applications source or sink power from the network-side center taps of the Rx/Tx transformers.

Figure 3. Voltage Suppression, Longitudinal Protection

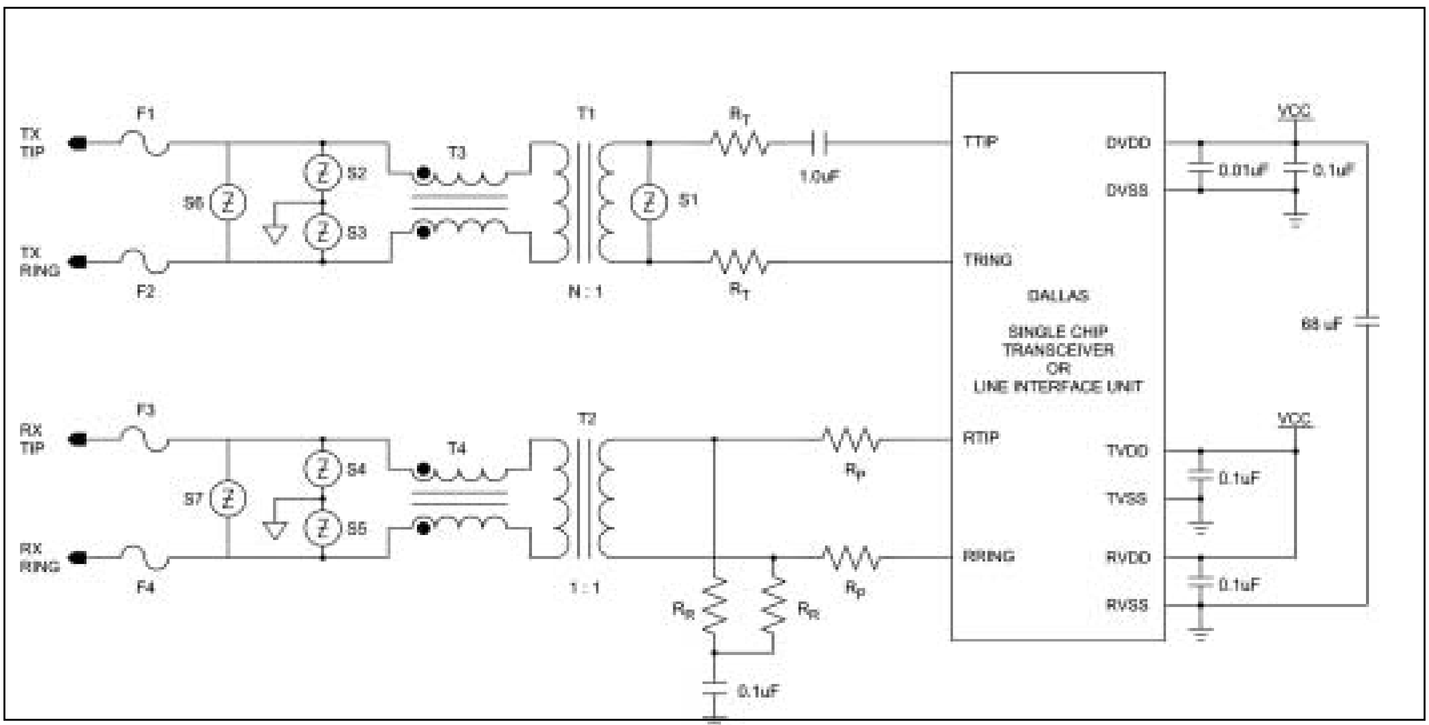

Table 4. Component List (Voltage Suppression, Longitudinal Protection)

NAME		DESCRIPTION	PART	MANUFACTURER	NOTE
F1, F2		1.25A Slow Blow Fuse	SMP 1.25	Bel Fuse	
		1.25A Slow Blow Fuse	F1250T	Teccor Electronics	
R_P		475Ω 1%, 1/8W	CRCW 1206 475R F	Vishay	
R_R	T1	50Ω 1%, 1/8W	CRCW 1206 49R9 F	Vishay	
	E1 75Ω	37.5Ω 1%, 1/8W	CRCW 1206 37R4 F	Vishay	
	E1 120Ω	60Ω 1%, 1/8W	CRCW 1206 60R4 F	Vishay	
R_T		Transmit Resistor (1%, 1/8W) (Note 1)	—	Vishay	3
S1		25V (max) Transient Suppressor	P0080SA MC	Teccor Electronics	
S2, S3, S4, S5		180V (max) Transient Suppressor	P1800SC MC	Teccor Electronics	
S6, S7		40V (max) Transient Suppressor (Note 2)	P0300SC MC	Teccor Electronics	5
T1 and T2		Transformer 1:1CT and 1:136CT (5.0V, SMT) (Note 3)	T1136	Pulse Engineering	4
T1 and T2		Transformer 1:1CT and 1:2CT (3.3V, SMT) (Note 3)	PE-68678	Pulse Engineering	4
T3 and T4		Dual Common-Mode Choke (SMT)	PE-65857	Pulse Engineering	

Note 1: The value of Rt is application dependent. Use the Dallas Semiconductor device data sheet for more information.
Note 2: Changing S6 and S7 to P1800SC devices provides symmetrical voltage suppresion between Tip, Ring, and Ground.
Note 3: Alternate transformer part numbers and manufacturers are located at the end of this application note.
Note 4: The layout from the transformers to the network interface is critical. Traces should be at least 25 mils wide and separated from other circuit lines by at least 150 mils. The area under this portion of the circuit should not contain power planes.
Note 5: Some T1 (never E1) applications source or sink power from the network-side center taps of the Rx/Tx transformers.
Note 6: The Ground trace connected to the S2/S3 pair and the S4/S5 pair should be at least 50 mils wide to conduct the extra current from a longitudinal power-cross event.

SOFTWARE SELECTED TERMINATION PROTECTION CIRCUITS

One of the new features of the Dallas DS2155 single chip transceiver and the DS2148 line interface unit is the software selected termination. Both the DS2155 and DS2148 contains internal resistors that allow the termination on the receive side to be selected through software. In addition to the internal receive side termination, the DS2155 provides internal transmitter impedance matching.

By default, the receive side circuit is designed for 120Ω termination throught the Rr resistors. The device then allows either a 600Ω or 200Ω internal resistance to be placed in parallel with the existing 120Ω termination. These settings allow the selection of 100Ω T1, 75Ω E1, or 120Ω E1 termination on the receive side without using external jumbers, switches, or changing resistors. Since the devices provide resistance in parallel with the R_T termination resistors, the two 470Ω R_P protection resistors have to be removed. A thyristors is used to protect the receiver inputs from transient voltage conditions

Although transmitter impedance matching is not specified for T1 applications, it is required for some E1 applications. The E1 applications usually specify a certain return loss that is implemented by matching the line impedance to the transmitter output impedance through the use of the external R_T resistors. The DS2155 allows the R_T resistors to be removed from the circuit and uses an internal resistance settings to achieve a return loss of 21dB for a line impedance of either 75Ω or 120Ω.

Like the previous design, this one benefits from the use of thyristors. One of the changes that was made in Figure 4 and Figure 5 was the removal of the R_P for protection of the receive circuitry. This is necessary to facilitate the use of the internal receive termination present in the device. Also, these circuits were designed for the DS2155 which does not use the R_T resistors. If these designs are used with the DS2148, it may be necessary to insert the R_T resistors in the transmit path. More information is available in the DS2148 data sheet.

Figure 4. Software Selected Termination, Metallic Protection

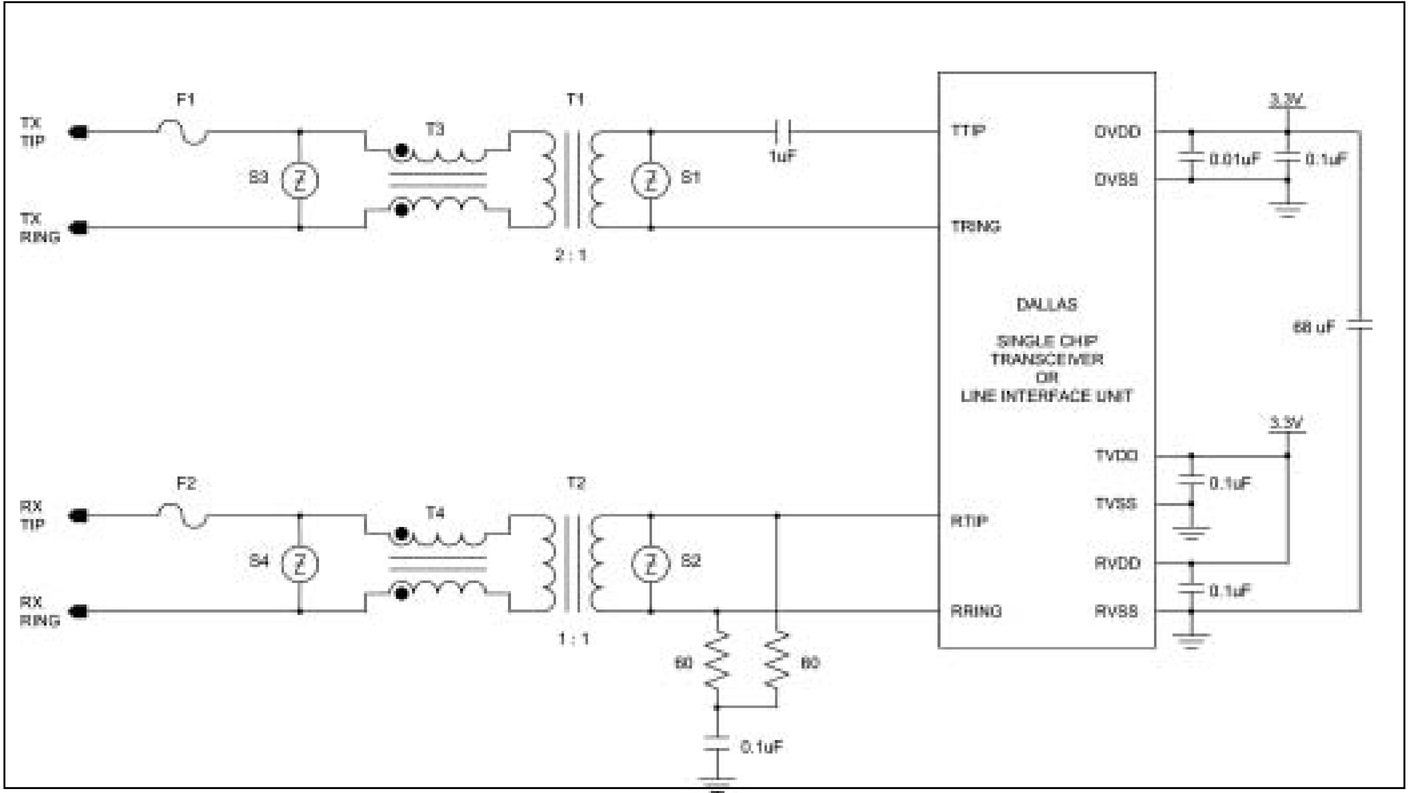

Table 5. Component List (Software Selected Termination, Metallic Protection)

NAME	DESCRIPTION	PART	MANUFACTURER
F1, F2	1.25A Slow Blow Fuse	SMP 1.25	Bel Fuse
	1.25A Slow Blow Fuse	F1250T	Teccor Electronics
S1, S2	25V (max) Transient Suppressor	P0080SA MC	Teccor Electronics
S3, S4	77V (max) Transient Suppressor	P0640SC MC	Teccor Electronics
T1 and T2	Transformer 1:1CT and 1:136CT (5.0V, SMT) (Note 1)	T1136	Pulse Engineering
T1 and T2	Transformer 1:1CT and 1:2CT (3.3V, SMT) (Note 1)	PE-68678	Pulse Engineering
T3 and T4	Dual Common-Mode Choke (SMT)	PE-65857	Pulse Engineering

Note 1: If the design uses the DS2148 or DS21348 in E1 mode, R_T may be necessary for transmit-impedance matching. Consult the Dallas Semiconductor device data sheet for more information

Note 2: The layout from the transformers to the network interface is critical. Traces should be at least 25 mils wide and separated from other circuit lines by at least 150 mils. The area under this portion of the circuit should not contain power planes.

Note 3: Some T1 (never in E1) applications source or sink power from the network-side center taps of the Rx/Tx transformers.

Note 4: Alternate transformer part numbers and manufacturers are located at the end of this application note.

Figure 5. Software Selected Termination, Longitudinal Protection

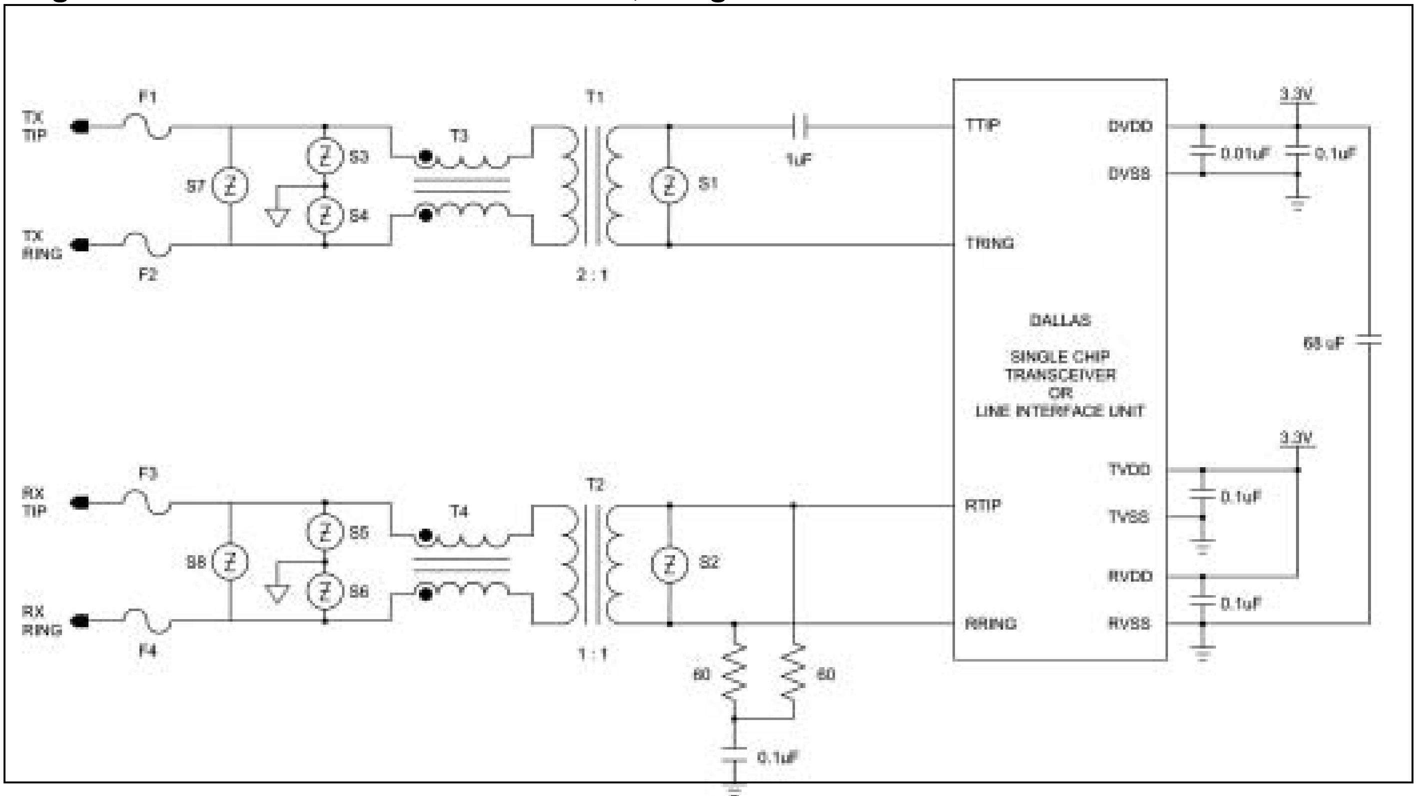

Table 6. Component List (Software Selected Termination, Longitudinal Protection)

NAME	DESCRIPTION	PART	MANUFACTURER
F1 to F4	1.25A Slow Blow Fuse	SMP 1.25	Bel Fuse
	1.25A Slow Blow Fuse	F1250T	Teccor Electronics
S1, S2	25V (max) Transient Suppressor (Note 1)	P0080SA MC	Teccor Electronics
S3, S4, S5, S6	180V (max) Transient Suppressor (Note 1)	P1800SC MC	Teccor Electronics
S7, S8	40V (max) Transient Suppressor	P0300SC MC	Teccor Electronics
T1 and T2	Transformer 1:1CT and 1:136CT (5.0V, SMT) (Note 2)	T1136	Pulse Engineering
T1 and T2	Transformer 1:1CT and 1:2CT (3.3V, SMT) (Note 2)	PE-68678	Pulse Engineering
T3 and T4	Dual Common-Mode Choke (SMT)	PE-65857	Pulse Engineering

Note 1: Changing S7 and S8 to P1800SC devices provides symmetrical voltage suppresion between Tip, Ring, and Ground.
Note 2: Alternate transformer part numbers and manufacturers are located at the end of this application note.
Note 3: The layout from the transformers to the network interface is critical. Traces should be at least 25 mils wide and separated from other circuit lines by at least 150 mils. The area under this portion of the circuit should not contain power planes.
Note 4: Some T1 (never in E1) applications source or sink power from the network-side center taps of the Rx/Tx transformers.
Note 5: If the design uses the DS2148 or DS21348 in E1 mode, R_T may be necessary for transmit-impedance matching. Consult the Dallas Semiconductor device data sheet for more information.
Note 6: The Ground trace connected to the S2/S3 pair and the S4/S5 pair should be at least 50 mils wide to conduct the extra current from a longitudinal power-cross event.

POWER RESISTOR PROTECTION CIRCUITS

The network interface circuit in Figure 6 uses a power resistor plus fuse combination on the line side of the transformers. The fuse is used to protect the transformer against a high current condition such as power line cross. The value of the fuse is set to match the maximum power dissipation or continuous current rating of the transformer. This information can be obtained by contacting the transformer manufacturer. Because fuses will typically break at 135% of their rating, this must be kept in mind during the component selection process. Typically the fuse will have surge current rating above 50A. If it is less than 100A, the fuse will have to be protected by a current limiting resistor. The model for what will pass through the primary protection circuit is 800V at 100A. If the fuse has a Surge Withstand greater than 100A such as the ones used in the following designs then the current limiting resistors are not needed. To conserve board space and reduce thermal dissipation, it is highly recommended that a fuse that does not require current limiting resistors be chosen.

Since the power resistors can have a resistance in the range of 5Ω to 10Ω, this design can only be used with 5.0V T1/E1 devices or 3.3V E1 devices. If these devices were used in 3.3V T1 applications, the transmiter would require a drive current in excess of 60mA.

Figure 6. Power Resistor Protection Network

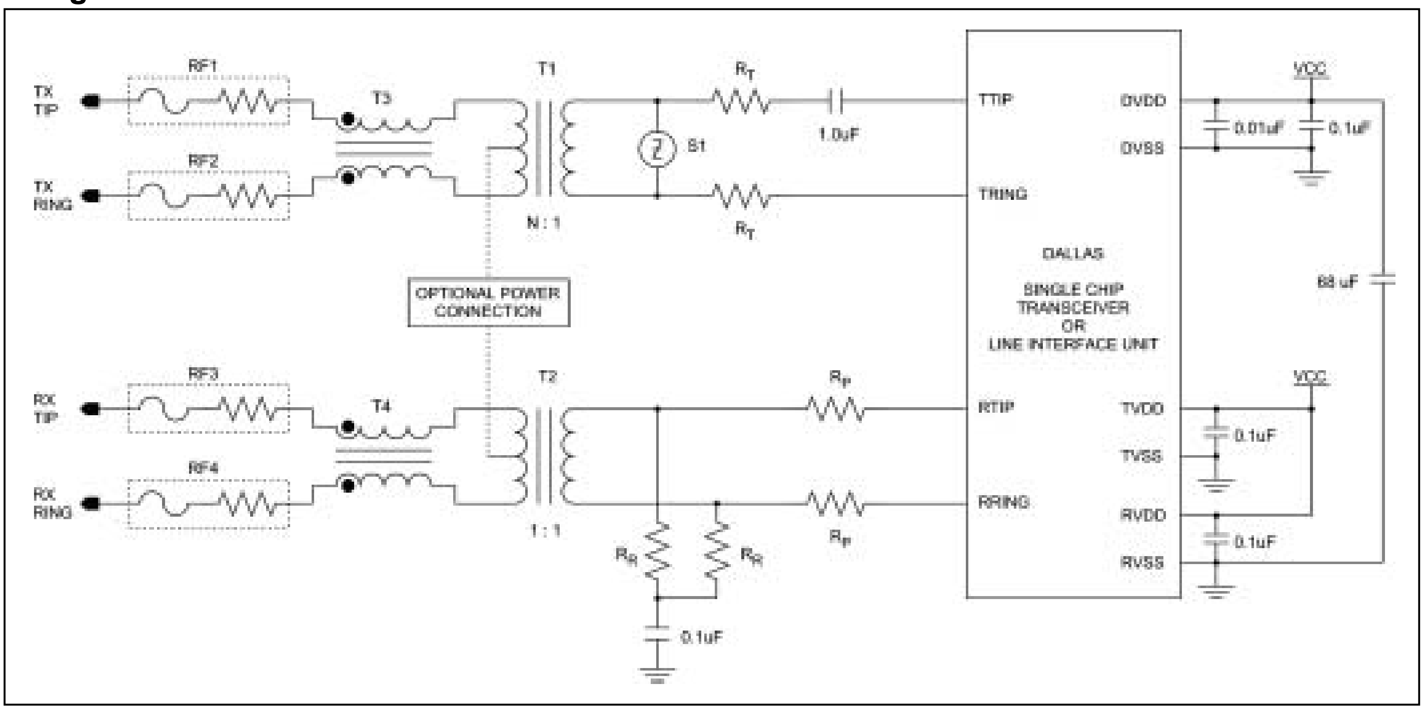

Table 7. Component List (Power Resistor Protection Network)

NAME		DESCRIPTION	PART	MANUFACTURER
RF1 to RF4		5.6Ω Power Resistor with Fuse (Note 1)	ALFR-2 1%, 2.0W	IRC Inc.
R_P		475Ω 1%, 1/8W	CRCW 1206 475R F	Vishay
R_R	T1	50 - 5.6 = 44.4Ω (1%, 1/8W) (Note 2)	CRCW 1206 44R2 F	Vishay
	E1 75Ω	37.5 - 5.6 = 31.9Ω (1%, 1/8W) (Note 2)	CRCW 1206 31R6 F	Vishay
	E1 120Ω	60 - 5.6 = 54.6Ω (1%, 1/8W) (Note 2)	CRCW 1206 54R9 F	Vishay
R_T	T1	5.5 - (5.6 / 1.36^2) = 2.5Ω (1%, 1/8W) (Note 2)	CRCW 1206 2R49 F	Vishay
	E1 75Ω	18 - (5.6 / 1.36^2) = 15Ω (1%, 1/8W) (Note 3)	CRCW 1206 15R0 F	Vishay
	E1 120Ω	27 - (5.6 / 1.36^2) = 24Ω (1%, 1/8W) (Note 3)	CRCW 1206 24R3 F	Vishay
S1		25V (max) Transient Suppressor	P0080SA MC	Teccor Electronics
T1 and T2		Transformer 1:1CT and 1:136CT (5.0V, SMT) (Note 4)	T1136	Pulse Engineering
T1 and T2		Transformer 1:1CT and 1:2CT (3.3V, SMT) (Note 4)	PE-68678	Pulse Engineering
T3 and T4		Dual Common-Mode Choke (SMT) (Note 4)	PE-65857	Pulse Engineering

Note 1: If using a separate resistor and fuse combination, the surge current rating of the fuse must be taken into consideration.
Note 2: Rr equations assume that R3 equals R4. The basic equation for Rr is: Rr = (Line Impedance / 2) - R3. Selecting a standard value for Rr within 2% is acceptable.
Note 3: Rt equations are for 5.0V devices and assume that R1 equals R2. When using the 3.3V E1 devices, substitute 6.2Ω and 11.6Ω for 18Ω and 27Ω and 2^2 for 1.36^2, respectively. Selecting a standard value for Rt within 2% is acceptable.
Note 4: Alternate transformer part numbers and manufacturers are located at the end of this application note.
Note 5: The layout from the transformers to the network interface is critical. Traces should be at least 25 mils wide and separated from other circuit lines by at least 150mils. The area under this portion of the circuit should not contain power planes.
Note 6: Some T1 (never E1) applications source or sink power from the network-side center taps of the Rx/Tx transformers.

PTC PROTECTION CIRCUITS

Positive-Temperature-Coefficient PTC devices such as the PolySwitch® from Raychem can be used in place of the resistor-fuse combination as shown in Figure 7. The advantage of these devices is that they will “reset” or “heal” after being exposed to over current conditions and do not need to be replaced like a fuse does. Because PTC devices vary significantly in resistance several considerations must be made when designing with them.

The first consideration is the resistance variability between individual devices. This coupled with the inter–winding capacitance of the transformer can upset the balance of a T1 or E1 line. Manufacturers may offers PTC devices which are “badged” to within 0.5Ω of each other. When used in this manner, the device should not cause excessive line imbalance.

Second, on the receive side these devices become part of the line termination. Any variance from part to part will directly affect the termination. On the transmit side this variance directly affects the output pulse amplitude as these devices form a voltage divider with the characteristic line impedance.

Finally, when using these devices is that when broken down or “tripped” the first time, the device will recover to a resistance that is 0.5Ω to 1.0Ω higher. This new resistance value is called the post trip resistance (Rpt) or Post Reflow resistance. It is therefore necessary to guarantee that all devices are exposed to electrical or environmental conditions (such as heat) that are sufficient enough to cause initial break down during the assembly process.

Since most PTC devices have a resistance in the range of 3Ω to 10Ω, this design can only be used with 5.0V T1/E1 devices or 3.3V E1 devices. If these devices were used in 3.3V T1 applications, the transmiter would require a drive current in excess of 60mA.

Note: PolySwitch is a registered trademark of Raychem Corporation. This circuit is shown as an example only and has not been tested by Dallas Semiconductor.

Figure 7. PTC Protection Network

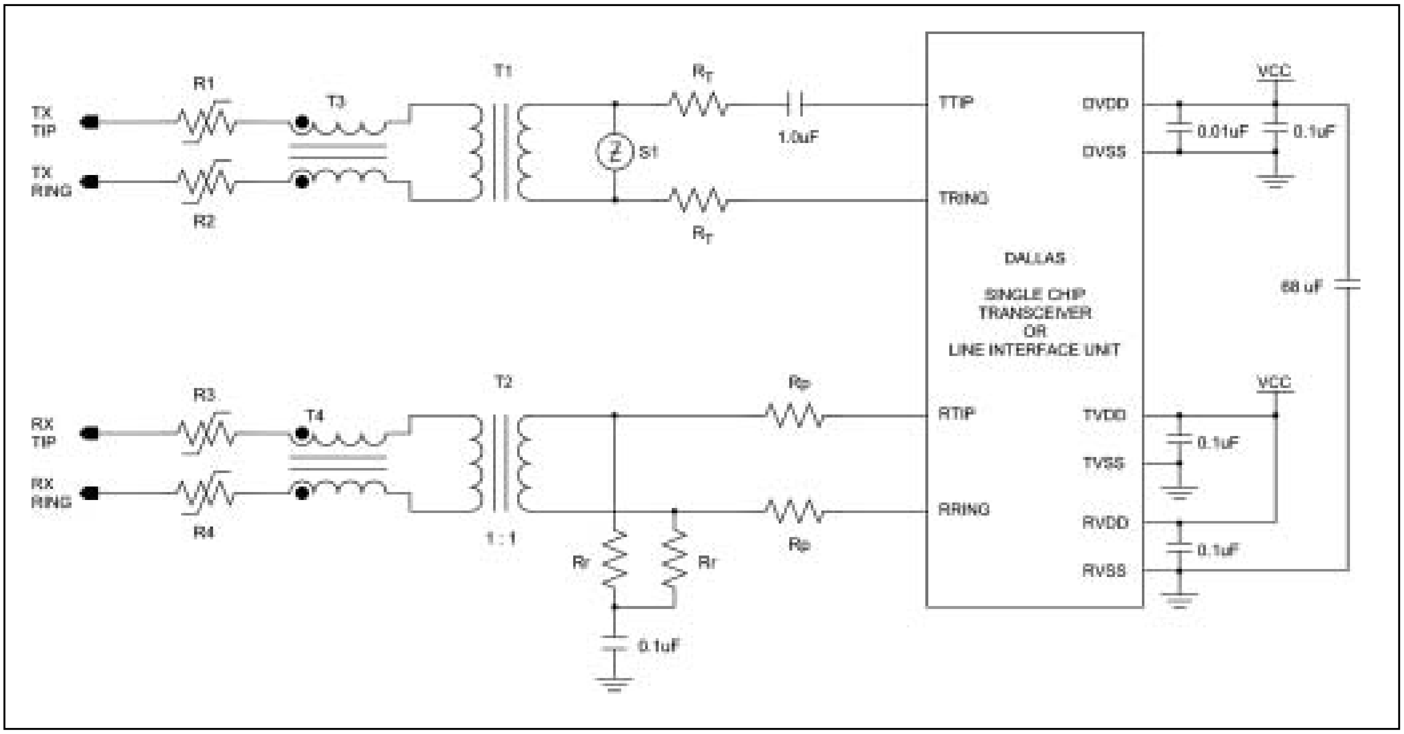

Table 8. Component List (PTC Protection Network)

NAME		DESCRIPTION	PART	MANUFACTURER
R_P		475Ω 1%, 1/8W	CRCW 1206 475R F	Vishay
R_R	T1	50 - 8 = 42Ω (1%, 1/8W) (Note 1)	CRCW 1206 42R2 F	Vishay
	E1 75Ω	37.5 - 8 = 29.5Ω (1%, 1/8W) (Note 1)	CRCW 1206 29R4 F	Vishay
	E1 120Ω	60 - 8 = 52Ω (1%, 1/8W) (Note 1)	CRCW 1206 52R3 F	Vishay
R_T	T1	5.5 - (8 / 1.36^2) = 1.2Ω (1%, 1/8W) (Note 1)	CRCW 1206 1R21 F	Vishay
	E1 75Ω	18 - (8 / 1.36^2) = 13.7Ω (1%, 1/8W) (Notes 1, 2)	CRCW 1206 13R7 F	Vishay
	E1 120Ω	27 - (8 / 1.36^2) = 22.7Ω (1%, 1/8W) (Notes 1, 2)	CRCW 1206 22R6 F	Vishay
R1 to R4		PTC Device (Note 1)	TS600-200-RA-2	Raychem
S1		25V (max) Transient Suppresser	P0080SA MC	Teccor Electronics
T1 and T2		Transformer 1:1CT and 1:136CT (5.0V, SMT) (Notes 2, 3)	T1136	Pulse Engineering
T1 and T2		Transformer 1:1CT and 1:2CT (3.3V, SMT)) (Notes 2, 3)	PE-68678	Pulse Engineering
T3 and T4		Dual Common-Mode Choke (SMT)	PE-65857	Pulse Engineering

Note 1: PTC devices vary in resistance over a given range. The TS600-200-RA-2 has a range of 1.0Ω to 7.0Ω with a nominal resistance of 3.0Ω and is binned in 0.5Ω incremnets. Since the post trip resistance is about 0.5Ω higher, the worst case is a 7.5Ω device (used in calculations).
Note 2: The value of Rt is application dependant, consult the data sheet for more information. These Rt equations are for 5.0V devices, when using the 3.3V E1 devices, 18Ω and 27Ω must be substituted with 6.2Ω and 11.6Ω, respectively.
Note 3: Alternate transformer part numbers and manufacturers are located at the end of this application note.
Note 4: The layout from the transformers to the network interface is critical. Traces should be at least 25 mils wide and separated from other circuit lines by at least 150 mils. The area under this portion of the circuit should not contain power planes.
Note 5: Some T1 (never in E1) applications source or sink power from the network-side center taps of the Rx/Tx transformers.

TRANSFORMER SPECIFICATIONS

The following is a list of transformer part numbers from a variety of vendors for use with the DS215x, DS21x5y, DS21Qx5y, DS2148 and the DS21Q48. The specifications for selecting an appropriate transformer are given in the table below.

SPECIFICATION	RECOMMENDED VALUE
Turns Ratio	1:1 (Rx) and 1:1.15, 1:1.36, or 1:2 (Tx) ±5%
Primary Inductance	600µH (min)
Leakage Inductance	1.0µH (max)
Inter-Winding Capacitance	40pF (max)
DC Resistance	1.2Ω (max)

VENDOR	PART	TURNS RATIO	PACKAGE TYPE	NO. OF PORTS	COMMERCIAL OR INDUSTRIAL	ISOLATION VOLTAGE
Bel Fuse	S553-3855-02*	1:1.15 & 1:1	Surface Mount	1	C	1500
	S553-0013-02*	1:1.36 & 1:1	Surface Mount	1	C	1500
	S553-0013-01	1:2 & 1:1	Surface Mount	1	C	1500
Halo	TG35-1505N1	1:1.15 & 1:1	Surface Mount	1	C	1500
	TG28-1505N1	1:1.36 & 1:1	Surface Mount	1	C	1500
	TG74-1205N1	1:2 & 1:1	Surface Mount	1	C	1500
InNet	T2028S*	1:1.15 & 1:1	Surface Mount	1	C	1500
	T2041S*	1:1.36 & 1:1	Surface Mount	1	C	1500
	T2032S	1:2 & 1:1	Surface Mount	1	C	1500
Midcom	50479R	1:1.15	Surface Mount	Tx only	C	1500
	50398R	1:1.36	Surface Mount	Tx only	C	1500
	50476R	1:2	Surface Mount	Tx only	C	1500
	50480R	1:1	Surface Mount	Rx only	C	1500
	50650R	1:1.15 & 1:1	Surface Mount	1	C	1500
	50652R	1:1.36 & 1:1	Surface Mount	1	C	1500
	50658R	1:2 & 1:1	Surface Mount	1	C	1500
Pulse	PE–65388	1:1.15	Through Hole	Tx only	C	1500
	PE–65586	1:1.36	Through Hole	Tx only	C	1500
	PE–65351	1:2	Through Hole	Tx only	C	1500
	PE–64936	1:1	Through Hole	Rx only	C	1500
	PE–65565*	1:1.15 & 1:1	Through Hole	1	C	1500
	PE–64952*	1:1.36 & 1:1	Through Hole	1	C	1500
	PE–64953*	1:2 & 1:1	Through Hole	1	C	1500
	PE–65865*	1:1.15 & 1:1	Surface Mount	1	C	1500
	T1136	1:1.36 & 1:1	Surface Mount	1	C	1500
	PE–68678	1:2 & 1:1	Surface Mount	1	C	1500
Vitec	46Z217*	1:1.15 & 1:1	Surface Mount	1	C	1500
	46Z216*	1:1.36 & 1:1	Surface Mount	1	C	1500
	46Z232	1:2 & 1:1	Surface Mount	1	C	1500

*These transformers are actually 1:2 with a center tap. 1:1 operation is obtained by connecting one end of the winding and the center tap, leaving the other end of the winding open.

VENDOR LIST

Bel Fuse Inc. 198 Van Vorst Street Jersey City, NJ 07302	Phone Fax Website	(201) 432-0463 (201) 432-9542 www.belfuse.com
Bothhand 462 Boston Street Topsfield, MA 01983	Phone Fax Website	(978) 887-8050 (978) 887-5434 www.bothhandusa.com
Halo Electronics Inc. P.O. Box 5826 Redwood City, CA 94063	Phone Fax Website	(650) 568-5800 (650) 568-6161 www.haloelectronics.com
InNet Technologies 10635 Scripps Ranch Blvd. Suite F San Diego, CA 92131	Phone Fax Website	(858) 578-8094 (858) 578-5762 www.innet-tech.com
Midcom Inc. 121 Airport Drive P.O. Box 1330 Watertown, SD 57201	Phone Fax Website	(800) 643-2661 (605) 886-4486 www.midcom-inc.com
Premier Magnetics Inc. 23081 Barents Sea Circle Lake Forest, CA 92630	Phone Fax Website	(949) 452-0511 (949) 452-0512 www.premiermag.com
Pulse 12220 World Trade Drive San Diego, CA 92128	Phone Fax Website	(858) 674-8100 (858) 674-8262 www.pulseeng.com
Schott 1000 Parkers Lake Road Wayzata, MN 55391	Phone Fax Website	(612) 475-1173 (612) 475-1786 www.schottcorp.com
Teccor Electronics 1800 Hurd Drive Irving, TX 75038	Phone Fax Website	(972) 580-7777 (972) 550-1309 www.teccor.com
Vitec Electronics Corporation 4027 Clipper Court Fremont, CA 94538	Phone Fax Website	(510) 353-9260 (510) 353-9836 www.viteccorp.com