

FEATURES

The Main features are as follows:

- Consists of Seven (7) Independent E1 (CEPT) Line Interface Units (Transmitter and Receiver)
- Generates Transmit Output Pulses that are Compliant with the ITU-T G.703 Pulse Template Requirement for 2.048Mbps (E1) Rates
- On-Chip Pulse Shaping for both 75Ω and 120Ω line drivers
- Receiver Can Either Be Transformer or Capacitive-Coupled to the Line
- Detects and Clears LOS (Loss of Signal) Per ITU-T G.775
- Compliant with the ITU-T G.823 Jitter Tolerance Requirements
- Compliant with ITU G.703 EOS Over-voltage protection Requirement

- Logic Inputs Accept Either 3.3V or 5.0V Levels
- Operates over the Industrial Temperature Range
- Ultra Low Power Dissipation
- +3.3V Supply Operation

APPLICATIONS

- PDH Multiplexers
- SDH Multiplexers
- Digital Cross-Connect Systems
- DECT (Digital European Cordless Telephone) Base Stations
- CSU/DSU Equipment

GENERAL DESCRIPTION

The XRT5997 is an optimized seven-channel analog E1 line interface unit fabricated using low power 3.3V CMOS technology. Each channel consists of both a Transmitter and a Receiver function. The Transmitter accepts a TTL or CMOS level signal from the Terminal Equipment; and outputs this data to the line via bipolar pulses that are compliant to the ITU-T G.703 pulse template for E1. The Receiver accepts an attenuated bipolar line signal (from the remote terminal equipment) and outputs this data to the (near-end) terminal equipment via CMOS level signals.

Each Receiver input can be transformer or capacitive-coupled to the line. The Receiver input is transformer-coupled to the line, using a 2:1 step-down transformer. Each Transmitter is coupled to the line using a 1:2 step-up transformer. This same configuration is applicable for both balanced (120Ω) and unbalanced (75Ω) interfaces.

ORDERING INFORMATION

Part No.	Package	Operating Temperature Range
XRT5997IV	100-Lead TQFP (14 x 14 x 1.4 mm)	-40°C to +85°C

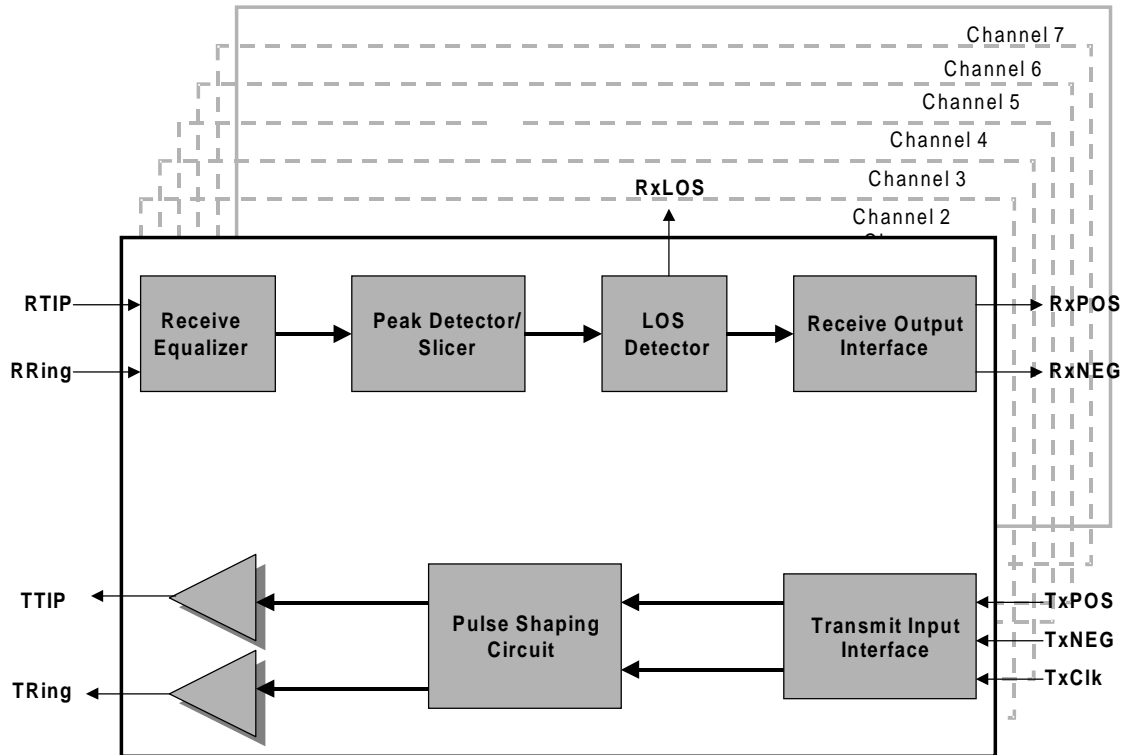
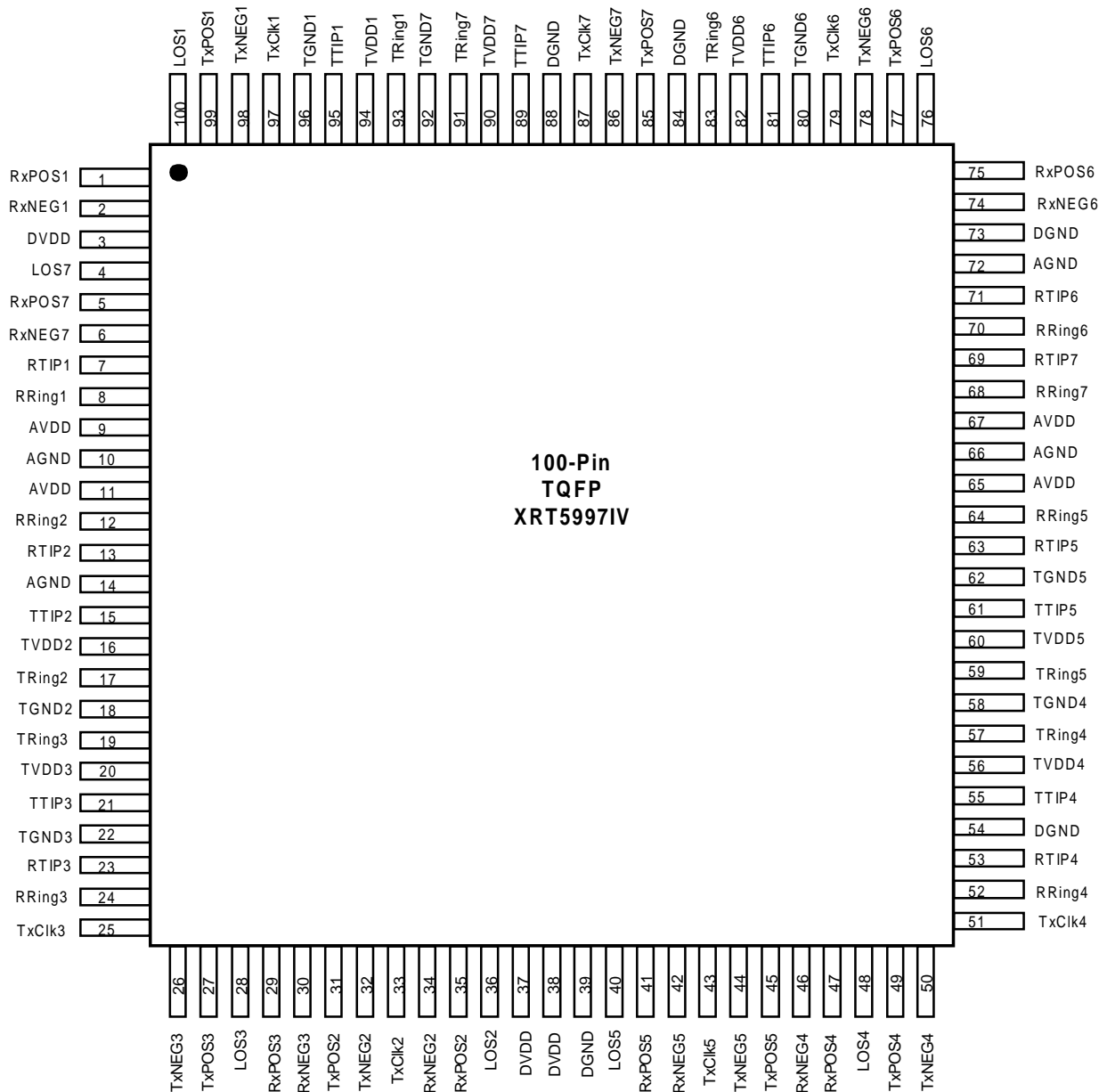


Figure 1. XRT5997 Block Diagram

PIN CONFIGURATION



**100 LEAD THIN QUAD FLAT PACK
(14 x 14 x 1.4 mm., TQFP)**

PIN DESCRIPTION

Pin#	Symbol	Type	Description
1	RxPOS1	O	Receiver 1 Positive Data Out: This output pin will pulse “high” whenever Channel 1, within the XRT5997 device has received a “Positive Polarity” pulse, in the incoming line signal, at RTIP1/RRing1 inputs.
2	RxNEG1	O	Receiver 1 Negative Data Out: This output pin will pulse “high” whenever Channel 1, within the XRT5997 device has received a “Negative Polarity” pulse, in the incoming line signal, at tRTIP1/RRing1 inputs.
3	DVDD	-	Positive Supply - (+3.3V ± 5%). Digital Circuitry.
4	LOS7	O	Receiver 7 Loss of Signal Output Indicator: This output pin toggles “high” if Channel 7, within the XRT5997 device has detected a “Loss of Signal” condition in the incoming line signal.
5	RxPOS7	O	Receiver 7 Positive Data Out: This output pin will pulse “high” whenever Channel 7, within the XRT5997 device has received a “Positive Polarity” pulse, in the incoming line signal, at RTIP7/RRing7 inputs.
6	RxNEG7	O	Receiver 7 Negative Data Out: This output pin will pulse “high” whenever Channel 7, within the XRT5997 device has received a “Negative Polarity” pulse, in the incoming line signal, at RTIP7/RRing7 inputs.
7	RTIP1	I	Receiver 1 Positive Bipolar Input: The Receive Section of Channel 1 uses this input pin, along with RRing1 to receive the bipolar line signal from the “Remote E1 Terminal”.
8	RRing1	I	Receiver 1 Negative Bipolar Input: The Receive Section of Channel 1 uses this input pin, along with RTIP1 to receive the bipolar line signal from the “Remote E1 Terminal”.
9	AVDD	-	Positive Supply - (+3.3V ± 5%). Analog Circuitry.
10	AGND	-	Analog Ground
11	AVDD	-	Positive Supply - (+3.3V ± 5%). Receiver 1, 2, 3, 5.
12	RRing2	I	Receiver 2 Negative Bipolar Input: The Receive Section of Channel 2 uses this input pin, along with RTIP2 to receive the bipolar line signal from the “Remote E1 Terminal”.
13	RTIP2	I	Receiver 2 Positive Bipolar Input: The Receive Section of Channel 2 uses this input pin, along with RRing2 to receive the bipolar line signal from the “Remote E1 Terminal”.

PIN DESCRIPTION (CONT'D)

Pin#	Symbol	Type	Description
14	AGND	-	Analog Ground - Receiver 1, 2, 3, 5.
15	TTIP2	O	Transmitter 2 Positive Bipolar Output: Channel 2 within the XRT5997 device will use this pin, along with TRing2, to transmit a bipolar line signal, via a 1:2 step-up transformer.
16	TVDD2	-	Positive Supply - (+3.3V ± 5%), Transmitters 2.
17	TRing2	O	Transmitter 2 Negative Bipolar Output: Channel 2 within the XRT5997 device will use this pin, along with TTIP2, to transmit a bipolar line signal, via a 1:2 step-up transformer.
18	TGND2		Digital Ground - Transmitters 2.
19	TRing3	O	Transmitter 3 Negative Bipolar Output: Channel 3 within the XRT5997 device will use this pin, along with TTIP3, to transmit a bipolar line signal, via a 1:2 step-up transformer.
20	TVDD3		Positive Supply - (+3.3V ± 5%), Transmitters 3.
21	TTIP3	O	Transmitter 3 Positive Bipolar Output: Channel 3 within the XRT5997 device will use this pin, along with TRing3, to transmit a bipolar line signal, via a 1:2 step-up transformer.
22	TGND3		Digital Ground - Transmitters 3.
23	RTIP3	I	Receiver 3 Positive Bipolar Input. The Receive Section of Channel 4 uses this input pin, along with RRing3 to receive the bipolar line signal from the "Remote E1 Terminal".
24	RRing3	I	Receiver 3 Negative Bipolar Input. The Receive Section of Channel 3 uses this input pin, along with RTIP3 to receive the bipolar line signal from the "Remote E1 Terminal".
25	TxCik3	I	Transmitter Clock Input – Channel 3: If the user operates Channel 3 (within the XRT5997 device) in the "clocked" mode, then the "Transmit Section" of the Channel 3 will use the falling edge of this signal to sample the data at the TxPOS3 and TxNEG3 input pins. <i>Note: If the user operates the Channel 3 in the "clockless" mode, then the Terminal Equipment should not apply a clock signal to this input pin.</i>

PIN DESCRIPTION (CONT'D)

Pin#	Symbol	Type	Description
26	TxNEG3	I	<p>Transmitter - Negative Data Input – Channel 3: The exact signal that should be applied to this input pin depends upon whether the user intends to operate the “Transmit Section” (of Channel 3) in the “Clocked” or “Clockless” Mode.</p> <p>Clocked Mode: The Terminal Equipment should apply bit-wide NRZ pulses on this input pin, whenever the Terminal Equipment needs to transmit a “negative-polarity” pulse onto the line via TTIP3 and TRing3 output pins. The XRT5997 device will sample this input pin upon the falling edge of the TClk3 signal.</p> <p>Clockless Mode: The Terminal Equipment should apply RZ pulses to this input pin, anytime the Terminal Equipment needs to transmit a “negative-polarity” pulse onto the line via TTIP3 and TRing3 output pins.</p>
27	TxPOS3	I	<p>Transmitter - Positive Data Input – Channel 3: The exact signal that should be applied to this input pin depends upon whether the user intends to operate the “Transmit Section” (of Channel 3) in the “Clocked” or “Clockless” Mode.</p> <p>Clocked Mode: The Terminal Equipment should apply bit-wide NRZ pulses on this input pin, whenever the Terminal Equipment needs to transmit a “positive-polarity” pulse onto the line via TTIP1 and TRing1 output pins. The XRT5997 device will sample this input pin upon the falling edge of the TClk1 signal.</p> <p>Clockless Mode: The Terminal Equipment should apply RZ pulses to this input pin, anytime the Terminal Equipment needs to transmit a “positive-polarity” pulse onto the line via TTIP1 and TRing1 output pins).</p>
28	LOS3	O	<p>Receiver 3 – Loss of Signal Output Indicator: This output pin toggles “high” if Channel 3, within the XRT5997 device has detected a “Loss of Signal” condition in the incoming line signal.</p>
29	RxPOS3	O	<p>Receiver 3 Positive Data Out: This output pin will pulse “high” whenever Channel 3, within the XRT5997 device has received a “Positive Polarity” pulse, in the incoming line signal, at RTIP3/RRing3 inputs.</p>

PIN DESCRIPTION (CONT'D)

Pin#	Symbol	Type	Description
30	RxNEG3	O	<p>Receiver 3 Negative Data Out: This output pin will pulse “high” whenever Channel 3, within the XRT5997 device has received a “Negative Polarity” pulse, in the incoming line signal, at RTIP3/RRing3 inputs.</p>
31	TxPOS2	I	<p>Transmitter - Positive Data Input – Channel 2: The exact signal that should be applied to this input pin depends upon whether the user intends to operate the “Transmit Section” (of Channel 2) in the “Clocked” or “Clockless” Mode.</p> <p>Clocked Mode: The Terminal Equipment should apply bit-wide NRZ pulses on this input pin, whenever the Terminal Equipment needs to transmit a “positive-polarity” pulse onto the line via TTIP2 and TRing2 output pins). The XRT5997 device will sample this input pin upon the falling edge of the TCik2 signal.</p> <p>Clockless Mode: The Terminal Equipment should apply RZ pulses to this input pin, anytime the Terminal Equipment needs to transmit a “positive-polarity” pulse onto the line via TTIP2 and TRing2 output pins.</p>
32	TxNEG2	I	<p>Transmitter - Negative Data Input – Channel 2: The exact signal that should be applied to this input pin depends upon whether the user intends to operate the “Transmit Section” (of the Channel 2) in the “Clocked” or “Clockless” Mode.</p> <p>Clocked Mode: The Terminal Equipment should apply bit-wide NRZ pulses on this input pin, whenever the Terminal Equipment needs to transmit a “negative-polarity” pulse onto the line via TTIP2 and TRing2 output pins. The XRT5997 device will sample this input pin upon the falling edge of the TCik2 signal.</p> <p>Clockless Mode: The Terminal Equipment should apply RZ pulses to this input pin, anytime the Terminal Equipment needs to transmit a “negative-polarity” pulse onto the line via TTIP2 and TRing2 output pins.</p>
33	TxCik2	I	<p>Transmitter Clock Input – Channel 2: If the user operates Channel 2 (within the XRT5997 device) in the “clocked” mode, then the “Transmit Section” of the Channel 2 will use the falling edge of this signal to sample the data at the TxPOS2 and TxNEG2 input pins.</p> <p>Note If the user operates the Channel 2 in the “clockless” mode, then the Terminal Equipment should not apply a clock signal to this input pin.</p>

Note: ¹ Internally pull-up with 50K resistor.

PIN DESCRIPTION (CONT'D)

Pin#	Symbol	Type	Description
34	RxNEG2	O	<p>Receiver 2 Negative Data Out: This output pin will pulse “high” whenever Channel 2, within the XRT5997 device has received a “Negative Polarity” pulse, in the incoming line signal, at RTIP2/RRing2 inputs.</p>
35	RxPOS2	O	<p>Receiver 2 Positive Data Out: This output pin will pulse “high” whenever Channel 2, within the XRT5997 device has received a “Positive Polarity” pulse, in the incoming line signal, at RTIP2/RRing2 inputs.</p>
36	LOS2	O	<p>Receiver 2 Loss of Signal: This output pin toggles “high” if Channel 2, within the XRT5997 device has detected a “Loss of Signal” condition in the incoming line signal.</p>
37	DVDD	-	Positive Supply (+3.3V ± 5%). Digital Circuitry.
38	DVDD	-	Positive Supply (+3.3V ± 5%). Digital Circuitry.
39	DGND	-	Digital Ground: Digital Circuitry.
40	LOS5	O	<p>Receiver 5 Loss of Signal: This output pin toggles “high” if Channel 5, within the XRT5997 device has detected a “Loss of Signal” condition in the incoming line signal.</p> <p><i>Note:</i> ¹Internally pull-up with 50K resistor</p>
41	RxPOS5	O	<p>Receiver 5 Positive Data Out: This output pin will pulse “high” whenever Channel 5, within the XRT5997 device has received a “Positive Polarity” pulse, in the incoming line signal, at RTIP5/RRing5 inputs.</p>
42	RxNEG5	O	<p>Receiver 5 Negative Data Out: This output pin will pulse “high” whenever Channel 5, within the XRT5997 device has received a “Negative Polarity” pulse, in the incoming line signal, at RTIP5/RRing5 inputs.</p>
43	TxCik5	I	<p>Transmitter Clock Input – Channel 5: If the user operates Channel 5 (within the XRT5997 device) in the “clocked” mode, then the “Transmit Section” of the Channel 5 will use the falling edge of this signal to sample the data at the TxPOS5 and TxNEG5 input pins.</p> <p>NOTE: If the user operates the Channel 5 in the “clockless” mode, then the Terminal Equipment should not apply a clock signal to this input pin.</p>

Note: ¹ Internally pull-up with 50K resistor.

PIN DESCRIPTION (CONT'D)

Pin#	Symbol	Type	Description
44	TxNEG5	I	<p>Transmitter - Negative Data Input – Channel 5: The exact signal that should be applied to this input pin depends upon whether the user intends to operate the “Transmit Section” (of the Channel 5) in “Clocked” or “Clockless” Mode.</p> <p>Clocked Mode: The Terminal Equipment should apply bit-wide NRZ pulses on this input pin, whenever the Terminal Equipment needs to transmit a “negative-polarity” pulse onto the line via TTIP5 and TRing5 output pins. The XRT5997 device will sample this input pin upon the falling edge of the TCLK5 signal.</p> <p>Clockless Mode: The Terminal Equipment should apply RZ pulses to this input pin, anytime the Terminal Equipment needs to transmit a “negative-polarity” pulse onto the line via TTIP5 and TRing5 output pins.</p>
45	TxPOS5	I	<p>Transmitter - Positive Data Input – Channel 5: The exact signal that should be applied to this input pin depends upon whether the user intends to operate the “Transmit Section” (of Channel 5) in the “Clocked” or “Clockless” Mode.</p> <p>Clocked Mode: The Terminal Equipment should apply bit-wide NRZ pulses on this input pin, whenever the Terminal Equipment needs to transmit a “positive-polarity” pulse onto the line via TTIP5 and TRing5 output pins. The XRT5997 device will sample this input pin upon the falling edge of the TCLK5 signal.</p> <p>Clockless Mode: The Terminal Equipment should apply RZ pulses to this input pin, anytime the Terminal Equipment needs to transmit a “positive-polarity” pulse onto the line via TTIP5 and TRing5 output pins.</p>
46	RxNEG4	O	<p>Receiver 4 Negative Data Out: This output pin will pulse “high” whenever Channel 4, within the XRT5997 device has received a “Negative Polarity” pulse, in the incoming line signal, at the RTIP4/RRing4 inputs.</p>
47	RxPOS4	O	<p>Receiver 4 Positive Data Out: This output pin will pulse “high” whenever Channel 4, within the XRT5997 device has received a “Positive Polarity” pulse, in the incoming line signal, at RTIP4/RRing4 inputs.</p>

PIN DESCRIPTION (CONT'D)

Pin#	Symbol	Type	Description
48	LOS4	O	<p>Receiver 4 Loss of Signal: This output pin toggles “high” if Channel 4, within the XRT5997 device has detected a “Loss of Signal” condition in the incoming line signal.</p>
49	TxPOS4	O	<p>Transmitter - Positive Data Input – Channel 4: The exact signal that should be applied to this input pin depends upon whether the user intends to operate the “Transmit Section” (of Channel 4) in the “Clocked” or “Clockless” Mode.</p> <p>Clocked Mode: The Terminal Equipment should apply bit-wide NRZ pulses on this input pin, whenever the Terminal Equipment needs to transmit a “positive-polarity” pulse onto the line via TTIP4 and TRing4 output pins). The XRT5997 device will sample this input pin upon the falling edge of the TClk4 signal.</p> <p>Clockless Mode: The Terminal Equipment should apply RZ pulses to this input pin, anytime the Terminal Equipment needs to transmit a “positive-polarity” pulse onto the line via TTIP4 and TRing4 output pins.</p>
50	TxNEG4	I	<p>Transmitter - Negative Data Input – Channel 4: The exact signal that should be applied to this input pin depends upon whether the user intends to operate the “Transmit Section” (of the Channel 4) in the “Clocked” or “Clockless” Mode.</p> <p>In the Clocked Mode: The Terminal Equipment should apply bit-wide NRZ pulses on this input pin, whenever the Terminal Equipment needs to transmit a “negative-polarity” pulse onto the line via the TTIP4 and TRing4 output pins. The XRT5997 device will sample this input pin upon the falling edge of the TClk4 signal.</p> <p>In the Clockless Mode: The Terminal Equipment should apply RZ pulses to this input pin, anytime the Terminal Equipment needs to transmit a “negative-polarity” pulse onto the line (via the TTIP4 and TRing4 output pins).</p>
51	TxCIk4	I	<p>Transmitter Clock Input – Channel 4: If the user operates Channel 4 (within the XRT5997 device) in the “clocked” mode, then the “Transmit Section” of the Channel 4 will use the falling edge of this signal to sample the data at the TxPOS4 and TxNEG4 input pins.</p> <p>Note: <i>If the user operates the Channel 4 in the “clockless” mode, then the Terminal Equipment should not apply a clock signal to this input pin.</i></p>
52	RRing4	I	<p>Receiver 4 Negative Bipolar Input: The Receive Section of Channel 4 uses this input pin, along with RTIP4 to receive the bipolar line signal from the “Remote E1 Terminal”.</p>

PIN DESCRIPTION (CONT'D)

Pin#	Symbol	Type	Description
53	RTIP4	I	Receiver 4 Positive Bipolar Input. The Receive Section of Channel 4 uses this input pin, along with RRing4 to receive the bipolar line signal from the "Remote E1 Terminal".
54	DGND		Digital Ground. Digital Circuitry.
55	TTIP4	O	Transmitter 4 Positive Bipolar Output. Channel 4 within the XRT5997 device will use this pin, along with TRing4, to transmit a bipolar line signal, via a 1:2 step-up transformer.
56	TVDD4		Positive Supply (+3.3V ± 5%), Transmitters 4.
57	TRing4	O	Transmitter 4 Negative Bipolar Output. Channel 4 within the XRT5997 device will use this pin, along with TTIP4, to transmit a bipolar line signal, via a 1:2 step-up transformer.
58	TGND4		Digital Ground. Transmitters 4.
59	TRing5	O	Transmitter 5 Negative Bipolar Output. Channel 5 within the XRT5997 device will use this pin, along with TTIP5, to transmit a bipolar line signal, via a 1:2 step-up transformer.
60	TVDD5		Positive Supply (+3.3V ± 5%), Transmitters 5.
61	TTIP5	O	Transmitter 5 Positive Bipolar Output. Channel 5 within the XRT5997 device will use this pin, along with TRing5, to transmit a bipolar line signal, via a 1:2 step-up transformer.
62	TGND5		Digital Ground. Transmitters 5.
63	RTIP5	I	Receiver 5 Positive Bipolar Input. The Receive Section of Channel 5 uses this input pin, along with RRing5 to receive the bipolar line signal from the "Remote E1 Terminal".
64	RRing5	I	Receiver 5 Negative Bipolar Input. The Receive Section of Channel 5 uses this input pin, along with RTIP5 to receive the bipolar line signal from the "Remote E1 Terminal".
65	AVDD		Positive Supply (+3.3V ± 5%). Analog Circuitry.
66	AGND		Analog Ground.
67	AVDD		Positive Supply (+3.3V ± 5%). Receiver 4, 6, 7.
68	RRing7	I	Receiver 7 Negative Bipolar Input. The Receive Section of Channel 7 uses this input pin, along with RTIP7 to receive the bipolar line signal from the "Remote E1 Terminal".

PIN DESCRIPTION (CONT'D)

Pin#	Symbol	Type	Description
69	RTIP7	I	Receiver 7 Positive Bipolar Input: The Receive Section of Channel 7 uses this input pin, along with RRing7 to receive the bipolar line signal from the "Remote E1 Terminal".
70	RRing6	I	Receiver 6 Negative Bipolar Input: The Receive Section of Channel 6 uses this input pin, along with RTIP6 to receive the bipolar line signal from the "Remote E1 Terminal".
71	RTIP6	I	Receiver 6 Positive Bipolar Input: The Receive Section of Channel 6 uses this input pin, along with RRing6 to receive the bipolar line signal from the "Remote E1 Terminal".
72	AGND		Analog Ground. Receiver 4, 6, 7.
73	DGND3		Digital Ground. Digital Circuitry.
74	RxNEG6	O	Receiver 6 Negative Data Out: This output pin will pulse "high" whenever Channel 6, within the XRT5997 device has received a "Negative Polarity" pulse, in the incoming line signal, at RTIP6/RRing6 inputs.
75	RxPOS6	O	Receiver 6 Positive Data Out: This output pin will pulse "high" whenever Channel 6, within the XRT5997 device has received a "Positive Polarity" pulse, in the incoming line signal, at RTIP6/RRing6 inputs.
76	LOS6	O	Receiver 6 Loss of Signal: This output pin toggles "high" if Channel 6, within the XRT5997 device has detected a "Loss of Signal" condition in the incoming line signal.
77	TxPOS6	I	Transmitter - Positive Data Input – Channel 6: The exact signal that should be applied to this input pin depends upon whether the user intends to operate the "Transmit Section" (of Channel 6) in the "Clocked" or "Clockless" Mode. Clocked Mode: The Terminal Equipment should apply bit-wide NRZ pulses on this input pin, whenever the Terminal Equipment needs to transmit a "positive-polarity" pulse onto the line via TTIP6 and TRing6 output pins. The XRT5997 device will sample this input pin upon the falling edge of the TClk6 signal. Clockless Mode: The Terminal Equipment should apply RZ pulses to this input pin, anytime the Terminal Equipment needs to transmit a "positive-polarity" pulse onto the line via TTIP6 and TRing6 output pins.

PIN DESCRIPTION (CONT'D)

Pin#	Symbol	Type	Description
78	TxNEG6	I	<p>Transmitter - Negative Data Input – Channel 6: The exact signal that should be applied to this input pin depends upon whether the user intends to operate the “Transmit Section” (of the Channel 6) in the “Clocked” or “Clockless” Mode.</p> <p>Clocked Mode: The Terminal Equipment should apply bit-wide NRZ pulses on this input pin, whenever the Terminal Equipment needs to transmit a “negative-polarity” pulse onto the line via TTIP6 and TRing6 output pins. The XRT5997 device will sample this input pin upon the falling edge of the TCik6 signal.</p> <p>Clockless Mode: The Terminal Equipment should apply RZ pulses to this input pin, anytime the Terminal Equipment needs to transmit a “negative-polarity” pulse onto the line via TIP6 and TRing6 output pins.</p>
79	TxCik6	I	<p>Transmitter Clock Input – Channel 6: If the user operates Channel 6 (within the XRT5997 device) in the “clocked” mode, then the “Transmit Section” of the Channel 6 will use the falling edge of this signal to sample the data at the TxPOS6 and TxNEG6 input pins.</p> <p><i>Note: If the user operates the Channel 6 in the “clockless” mode, then the Terminal Equipment should not apply a clock signal to this input pin.</i></p>
80	TGND6		Digital Ground. Transmitters 6.
81	TTIP6	O	<p>Transmitter 6 Positive Bipolar Output: Channel 6 within the XRT5997 device will use this pin, along with TRing6, to transmit a bipolar line signal, via a 1:2 step-up transformer.</p>
82	TVDD6		Positive Supply (+3.3V ± 5%), Transmitters 6.
83	TRing6	O	<p>Transmitter 6 Negative Bipolar Output: Channel 6 within the XRT5997 device will use this pin, along with TTIP6, to transmit a bipolar line signal, via a 1:2 step-up transformer.</p>
84	DGND		Digital Ground. Digital Circuitry.

PIN DESCRIPTION (CONT'D)

Pin#	Symbol	Type	Description
85	TxPOS7	I	<p>Transmitter - Positive Data Input – Channel 7: The exact signal that should be applied to this input pin depends upon whether the user intends to operate the “Transmit Section” (of Channel 7) in the “Clocked” or “Clockless” Mode.</p> <p>Clocked Mode: The Terminal Equipment should apply bit-wide NRZ pulses on this input pin, whenever the Terminal Equipment needs to transmit a “positive-polarity” pulse onto the line via TTIP7 and TRing7 output pins. The XRT5997 device will sample this input pin upon the falling edge of the TClk7 signal.</p> <p>Clockless Mode: The Terminal Equipment should apply RZ pulses to this input pin, anytime the Terminal Equipment needs to transmit a “positive-polarity” pulse onto the line via TTIP7 and TRing7 output pins.</p>
86	TxNEG7	I	<p>Transmitter - Negative Data Input – Channel 7:</p>
87	TxCIk7	I	<p>Transmitter Clock Input – Channel 7: If the user operates Channel 7 (within the XRT5997 device) in the “clocked” mode, then the “Transmit Section” of the Channel 7 will use the falling edge of this signal to sample the data at the TxPOS7 and TxNEG7 input pins.</p> <p><i>Note: If the user operates the Channel 7 in the “clockless” mode, then the Terminal Equipment should not apply a clock signal to this input pin.</i></p>
88	DGND		<p>Digital Ground: Digital Circuitry.</p>
89	TTIP7	O	<p>Transmitter 7 Positive Bipolar Output: Channel 7 within the XRT5997 device will use this pin, along with TRing7, to transmit a bipolar line signal, via a 1:2 step-up transformer.</p>
90	TVDD7		<p>Positive Supply: (+3.3V ± 5%), Transmitters 7.</p>
91	TRing7	O	<p>Transmitter 7 Negative Bipolar Output: Channel 7 within the XRT5997 device will use this pin, along with TTIP7, to transmit a bipolar line signal, via a 1:2 step-up transformer.</p>
92	TGND7		<p>Digital Ground: Transmitters 7.</p>
93	TRing1	O	<p>Transmitter 1 Negative Bipolar Output: Channel 1 within the XRT5997 device will use this pin, along with TTIP1, to transmit a bipolar line signal, via a 1:2 step-up transformer.</p>
94	TVDD1		<p>Positive Supply (+3.3V ± 5%), Transmitters 1.</p>

PIN DESCRIPTION (CONT'D)

Pin#	Symbol	Type	Description
95	TTIP1	O	<p>Transmitter 1 Positive Bipolar Output. Channel 1 within the XRT5997 device will use this pin, along with TRing1, to transmit a bipolar line signal, via a 1:2 step-up transformer.</p>
96	TGND1		<p>Digital Ground. Transmitters 1.</p>
97	TxCk1	I	<p>Transmitter Clock Input – Channel 1: If the user operates Channel 1 (within the XRT5997 device) in the “clocked” mode, then the “Transmit Section” of the Channel 1 will use the falling edge of this signal to sample the data at the TxPOS1 and TxNEG1 input pins.</p> <p><i>Note: If the user operates the Channel 1 in the “clockless” mode, then the Terminal Equipment should not apply a clock signal to this input pin..</i></p>
98	TxNEG1	I	<p>Transmitter - Negative Data Input – Channel 1: The exact signal that should be applied to this input pin depends upon whether the user intends to operate the “Transmit Section” (of the Channel 1) in the “Clocked” or “Clockless” Mode.</p> <p>Clocked Mode: The Terminal Equipment should apply bit-wide NRZ pulses on this input pin, whenever the Terminal Equipment needs to transmit a “negative-polarity” pulse onto the line via TTIP1 and TRing1 output pins. The XRT5997 device will sample this input pin upon the falling edge of the TCk1 signal.</p> <p>Clockless Mode: The Terminal Equipment should apply RZ pulses to this input pin, anytime the Terminal Equipment needs to transmit a “negative-polarity” pulse onto the line via TTIP1 and TRing1 output pins.</p>
99	TxPOS1	I	<p>Transmitter - Positive Data Input – Channel 1: The exact signal that should be applied to this input pin depends upon whether the user intends to operate the “Transmit Section” (of Channel 1) in the “Clocked” or “Clockless” Mode.</p> <p>Clocked Mode: The Terminal Equipment should apply bit-wide NRZ pulses on this input pin, whenever the Terminal Equipment needs to transmit a “positive-polarity” pulse onto the line via TTIP1 and TRing1 output pins. The XRT5997 device will sample this input pin upon the falling edge of the TCk1 signal.</p> <p>Clockless Mode: The Terminal Equipment should apply RZ pulses to this input pin, anytime the Terminal Equipment needs to transmit a “positive-polarity” pulse onto the line via TTIP1 and TRing1 output pins.</p>
100	LOS1	O	<p>Receiver 1 Loss of Signal: This output pin toggles “high” if Channel 1, within the XRT5997 device has detected a “Loss of Signal” condition in the incoming line signal.</p>

RECEIVER ELECTRICAL CHARACTERISTICS

Unless otherwise specified: $T_A = -40$ to 85°C , $V_{DD} = 3.3\text{V} \pm 5\%$, unless otherwise specified.

Parameter	Min	Typ	Max	Unit	Test Conditions
Receiver Loss of Signal:					
Threshold to Assert	12	20	-	dB	Cable attenuation @ 1024KHz
Threshold to Clear	11	15		dB	Per ITU-G.775
Time Delay	10	-	255	bit	
Hysteresis	-	5	-	dB	
Receiver Sensitivity	11	13	-	dB	Below nominal pulse amplitude of 3.0V for 120 Ω and 2.37V for 75 Ω applications. With -18dB interference signal added.
Interference Margin	-18	-14	-	dB	With 6dB cable loss.
Input Impedance	5	-	-	K Ω	
Jitter Tolerance:					
20Hz	10			UIpp	
700Hz	5	-	-		
10KHz —100KHz	0.3				
Return Loss:					
51KHz —102KHz	14	-	-	dB	Per ITU-G.703
102KHz—2048KHz	20	-	-	dB	
2048KHz—3072KHz	16	-	-	dB	

TRANSMITTER ELECTRICAL CHARACTERISTICS

Unless otherwise specified: $T_A = -40$ to 85°C , $V_{DD} = 3.3\text{V} \pm 5\%$, unless otherwise specified.

Parameter	Min	Typ	Max	Unit	Test Conditions
AMI Output Pulse Amplitude:					
75 Ω Application	2.13	2.37	2.60	V	Use transformer with 1:2 ratio and 9.1 Ω resistor in series with each end of primary.
120 Ω Application	2.70	3.0	3.30	V	
Output Pulse Width	224	244	264	ns	
Output Pulse Width Ratio	0.95	—	1.05	—	Per ITU-G.703
Output Pulse Amplitude Ratio	0.95	—	1.05	—	Per ITU-G.703
Output Return Loss:					
51KHz —102KHz	10	-	-	dB	Per ETSI 300 166 and CH PTT
102KHz—2048KHz	16	-	-	dB	
2048KHz—3072KHz	12	-	-	dB	

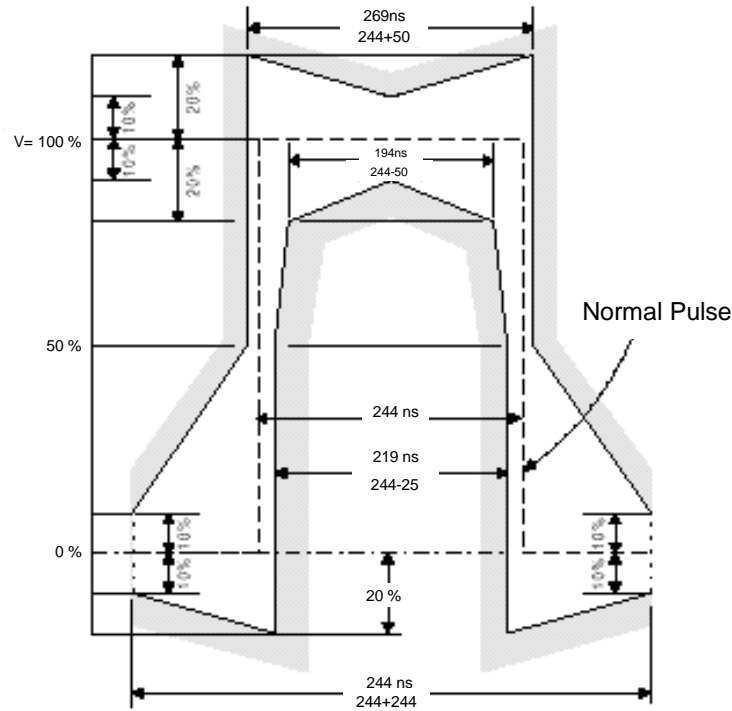


Figure E1. ITU G.703 Pulse Template for Transmitter Output

DC ELECTRICAL CHARACTERISTICS

$T_A = -25^\circ\text{C}$, $V_{DD} = 3.3\text{V} \pm 5\%$, unless otherwise specified.

Parameter	Symbol	Min	Typ	Max	Unit
Power Supply Voltage	VDD	3.13	3.3	3.46	V
Input High Voltage	VIH	2.0	-	5.0	V
Input Low Voltage	VIL	-0.5	-	0.8	V
Output High Voltage @ IOH=-5mA	VOH	2.4	-	-	V
Output Low Voltage @ IOL=5mA	VOL	-	-	0.4	V
Input Leakage Current (except Input pins w/ pull-up resistor.)	IL	-	-	± 10	μA
Input Capacitance	CI	-	5.0	-	pF
Output Load Capacitance	CL	-	-	25	pF

AC ELECTRICAL CHARACTERISTICS

$T_A = -25^{\circ}\text{C}$, $V_{DD} = 3.3\text{V} \pm 5\%$, unless otherwise specified.

Parameter	Symbol	Min	Typ	Max	Unit
TCLK Clock Period	T_1	-	488	-	ns
TCLK Duty Cycle	T_2	47	50	53	%
Transmit Data Setup Time	T_{SU}	50	-	-	ns
Transmit Data Hold Time	T_{HO}	30	-	-	ns
Transmit Data Prop. Delay Time	T_3				
- RZ data Mode		-	30	-	ns
- NRZ data Mode (clock mode)		-	30	-	ns
TCLK Rise Time(10%/90%)	T_R	-	-	40	ns
TCLK Fall Time(90%/10%)	T_F	-	-	40	ns
Receive Data Rise Time	R_{tr}	-	-	40	ns
Receive Data Fall Time	R_{tf}	-	-	40	ns
Receive Data Prop. Delay	R_{pd}	-	75	-	ns
Receive Data Pulse Width	Rxpw	200	244	350	ns

Per channel power consumption including the line power dissipation, transmission and receive paths all active: $T_A = -40$ to 85°C , $V_{DD} = 3.3\text{V} \pm 5\%$, unless otherwise specified.

Parameter	Symbol	Min	Typ	Max	Unit	Conditions
Power Consumption	PC	-	85	95	mW	75 Ω load, operating at 50% Mark Density.
Power Consumption	PC	-	72	80	mW	120 Ω load, operating at 50% Mark Density.
Power Consumption	PC	-	135	144	mW	75 Ω load, operating at 100% Mark Density.
Power Consumption	PC	-	106	115	mW	120 Ω load, operating at 100% Mark Density.
Power Consumption	PC	-	16	18	mW	Transmitter in Powered-down mode.

ABSOLUTE MAXIMUM RATINGS

Storage Temperature -65°C to $+150^{\circ}\text{C}$

Operating Temperature -40°C to $+85^{\circ}\text{C}$

ESD Rating $>4000\text{V}$ on all pins²

Supply Voltage -0.5V to $+6.0\text{V}$

Note: ² Human Body Model, 100pF capacitor discharged through a 1.5K Ω resistor.

SYSTEM DESCRIPTION

The XRT5997 device is a Seven (7) channel E1 transceiver that provides an electrical interface for 2.048Mbps applications. Each of the seven channels includes a receive circuit that converts an ITU-T G.703 compliant bipolar signal into a TTL compatible logic levels. Each receiver also includes an LOS (Loss of Signal) detection circuit. Similarly, in the Transmit Direction, each Transmitter converts TTL compatible logic levels into a G.703 compatible bipolar signal. The Transmitter may be operated in either a “Clocked” or “Clockless” Mode.

Each channel within the XRT5997 LIU device consists of both a Transmit Section and a Receive Section, each of these sections will be discussed in detail below.

1.0 The Transmit Section

In general, the purpose of the “Transmit Section” (within each channel of the XRT5997 device) is to accept TTL/CMOS level digital data (from the Terminal Equipment), and to encode it into a format such that it can:

1. Be efficiently transmitted over coaxial- or twisted-pair cable at the E1 data rate; and
2. Be reliably received by the Remote Terminal Equipment at the other end of the E1 data link.
3. Comply with the ITU-T G.703 pulse template requirements, for E1 applications.

The circuitry that the Transmit Section (within the XRT5997 device) uses to accomplish this goal is discussed below. The Transmit Section of the XRT5997 device consists of the following blocks:

- Transmit Input Interface
- Pulse Shaping Block

1.1 The Transmit Input Interface

The Transmit Input Interface accepts either “clocked” or “clockless” data from the Terminal Equipment. The manner in how the Terminal Equipment should apply data to a given channel within the XRT5997 device depends upon whether the channel is being operated in the “clocked” or “clockless” mode.

1.2.1 Operating the Transmitter in the Clocked Mode

The user can configure a given channel (within the XRT5997 device) to operate in the “Clocked” mode by simply applying a 2.048MHz clock signal to the “TxClk_x” input pin (where x denotes a given channel within the XRT5997 device). The XRT5997 device contains some circuitry that sense activity on the “TxClk_x” line. If this circuit senses activity on the “TxClk_x” line, then the corresponding channel will automatically be operating in the “Clocked” Mode.

In the Clocked Mode, the Terminal Equipment is expected to apply a 2.048MHz clock signal at the TxClk_x input pin and NRZ data at the TxPOS_x and TxNEG_x input pins. The “Transmit Input Interface” circuit will sample the data, at the TxPOS_x and TxNEG_x input pins, upon the falling edge of TxClk_x, as illustrated in Figure 3.

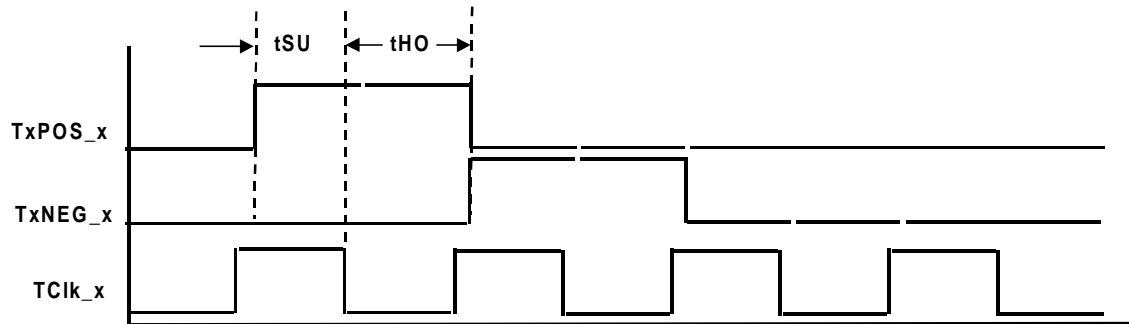


Figure 2. Illustration on how the XRT5997 Device Samples the data on the TxPOS_x and TxNEG_x input pins

In general, if the XRT5997 device samples a “1” on the TxPOS_x input pin, then the “Transmit Section” of the device will ultimately generate a positive polarity pulse via the TTIP_x and TRing_x output pins (across a 1:2 transformer). Conversely, if the XRT5997 device samples a “1” on the “TxNEG_x” input pin, then the “Transmit Section” of the device will ultimately generate a negative polarity pulse via the TTIP_x and TRing_x output pins (across a 1:2 transformer).

1.2.1 Operating the Transmitter in the “Clockless” Mode

The user can configure a given channel (within the XRT5997 device) to operate in the “Clockless” mode by doing the following:

- Not applying a clock signal to the TxCIk_x input, and either pulling this pin to VDD or letting it float.
- By applying RZ (Return to Zero) data to the TxPOS_x and TxNEG_x input pins, as illustrated below.

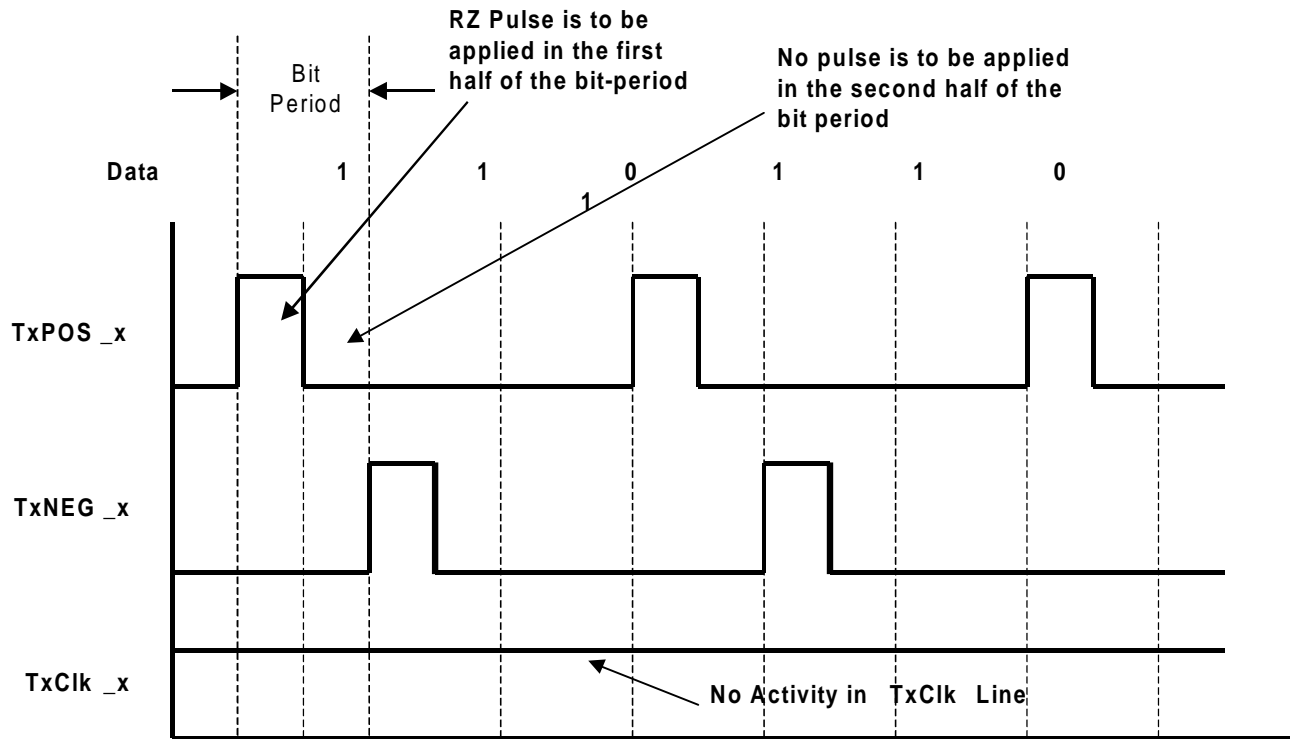


Figure 3. Illustration on how the Terminal Equipment should apply data to the “Transmit Section” of a given Channel (within the XRT5997 Device), when operating in the “Clockless” Mode

Figure 3, indicates that when the user is operating a channel in the “Clockless” Mode, then the corresponding Terminal Equipment must do the following:

- Not apply a signal on the “TxClk_x” line.
- When applying a pulse (to either the TxPOS_x or TxNEG_x input pin), apply an RZ pulse to the appropriate input pin. This RZ pulse should only have a width of one-half the bit-period. Addition, the RZ pulse should occupy only the first half of the bit-period. The TxPOS_x and TxNEG_x input pins must be at 0V, during the second half of every bit-period.

1.3 The Pulse Shaping Circuit

The purpose of the “Transmit Pulse Shaping” circuit is to generate “Transmit Output” pulses that comply with the ITU-T G.703 Pulse Template Requirements for E1 Applications.

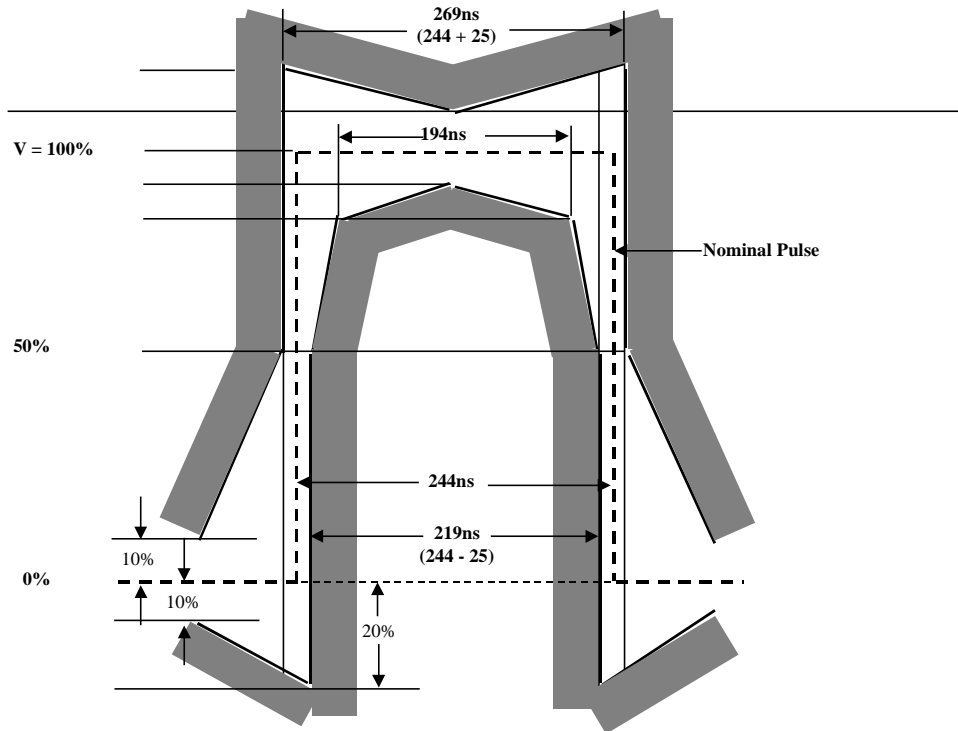


Figure 4. Illustration of the ITU-T G.703 Pulse Template for E1 Applications

As a consequence, each channel (within the XRT5997 device) will take each mark (which is provided to it via the “Transmit Input Interface” block, and will generate a pulse that complies with the pulse template, presented in Figure 4, (when measured on the secondary-side of the Transmit Output Transformer).

1.4 Interfacing the Transmit Sections of the XRT5997 device to the Line

ITU-T G.703 specifies that the E1 line signal can be transmitted over coaxial cable and terminated with 75Ω or transmitted over twisted-pair and terminated with 120Ω .

However, in both applications (e.g., 75Ω or 120Ω), the user is advised to interface the Transmitter to the Line, in the manner as depicted in Figures 5 and 6, respectively.

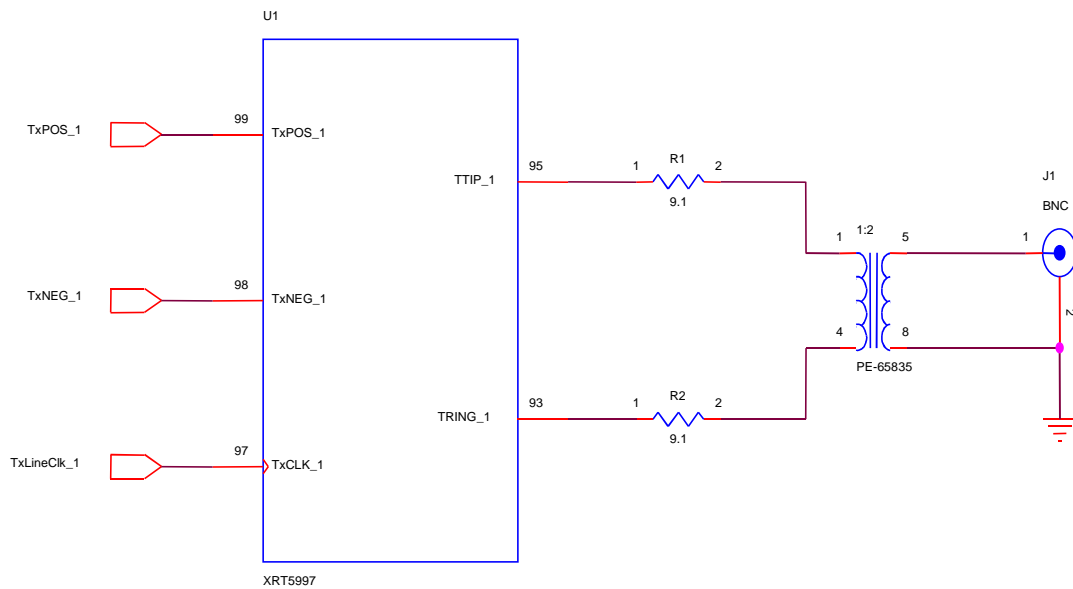


Figure 5. Illustration of how to interface the Transmit Sections of the XRT5997 device to the Line (for “75Ω ” Applications)

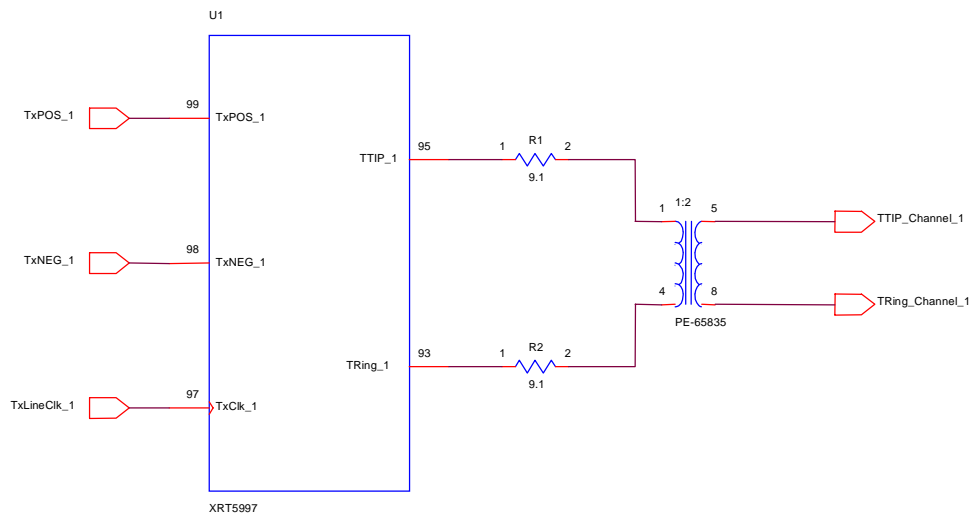


Figure 6. Illustration of how to interface the Transmit Sections the XRT5997 device to the Line (for “120Ω ” Applications)

Notes:

1. Figures 5 and 6, indicate that for both “75Ω” and “120Ω” applications, the user should connect a 9.1Ω resistor, in series, between the TTIP/TRing outputs and the transformers.
2. Figure 5 and 6, indicate that the user should use a “1:2 STEP-UP” Transformer.

Transmit Transformer Recommendations

Parameter	Value
Turns Ratio	1:2
Primary Inductance	
Isolation Voltage	
Leakage Inductance	

The following Transformers are Recommended for Use

Part Number	Vendor	Isolation	Package Type
PE-65835	Pulse		
TTI 7154-R	Transpower Technologies, Inc.		
TG26-1205	HALO		

Note: More transformers will be added to this list as we take the time to evaluate these transformers.

Magnetic Supplier Information

Pulse

Corporate Office

12220 World Trade Drive
San Diego, CA 92128
Tel: (619)-674-8100
FAX: (619)-674-8262

Europe

1 & 2 Huxley Road
The Surrey Research Park
Guildford, Surrey GU2 5RE
United Kingdom
Tel: 44-1483-401700
FAX: 44-1483-401701

Asia

150 Kampong Ampat
#07-01/02
KA Centre
Singapore 368324
Tel: 65-287-8998
FAX: 65-280-0080

Transpower Technologies

Corporate Office

9410 Prototype Drive, Ste #1
Reno, NV 89511
Tel: (800)511-7308 or
(775)852-0140
Fax: (775)852-0145
www.trans-power.com

HALO Electronics

P.O. Box 5826
Redwood City, CA 94063
Tel: (650)568-5800
FAX: (650)568-6161

2.0 The Receive Section

The Receive Sections of the XRT5997 device consists of the following blocks:

- The “Receive Equalizer” block
- The “Peak Detector” and “Slicer” block
- The “LOS Detector” block
- The “Receive Output Interface” block

2.1 Interfacing the Receive Sections to the Line

The design of each channel (within the XRT5997 device) permits the user to transformer-couple or capacitive-couple the Receive Section to the line. Additionally, as mentioned earlier, the specification documents for E1 specify 75Ω termination loads, when transmitting over coaxial cable, and 120Ω loads, when transmitting over twisted-pair. Figures 7 , through 9 present the various methods that the user can employ in order to interface the Receivers (of the XRT5997 device) to the line.

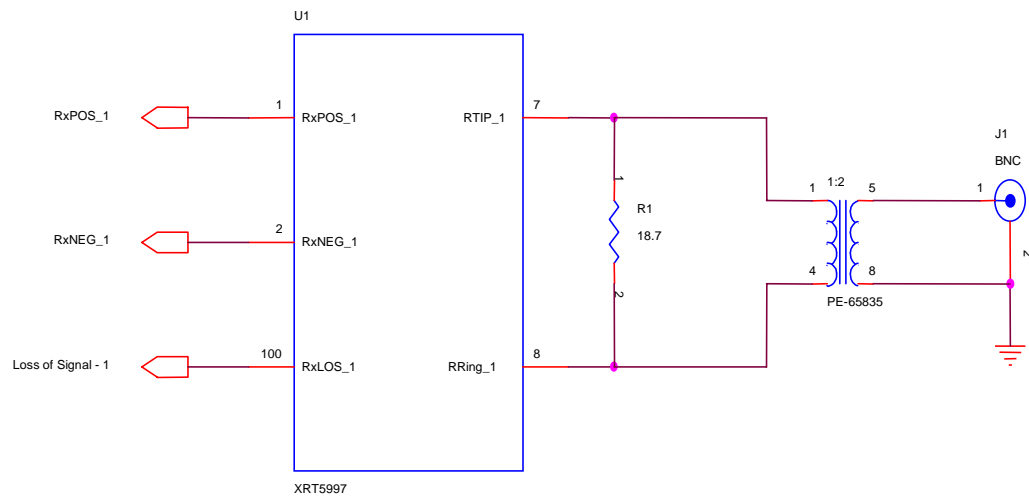


Figure 7. Recommended Schematic for Interfacing the Receive Sections of the XRT5997 Device to the Line for 75Ω Applications (Transformer-Coupling)

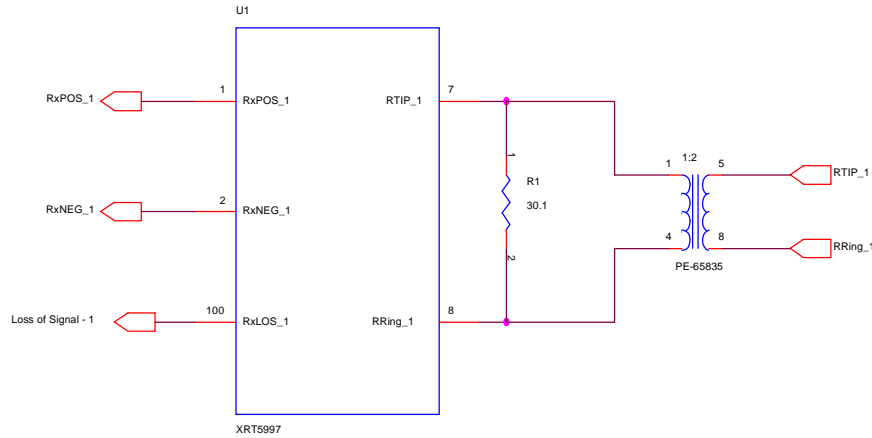


Figure 8. Recommended Schematic for Interfacing the Receive Sections of the XRT5997 Device to the Line for 120Ω Applications (Transformer-Coupling)

Note:

Figures 7 and 8 indicate that the user should use a “2:1 STEP-DOWN” transformer, when interfacing the receiver to the line.

Transmit Transformer Recommendations

Parameter	Value
Turns Ratio	1:2
Primary Inductance	
Isolation Voltage	
Leakage Inductance	

The following Transformers are Recommended for Use

Part Number	Vendor	Isolation	Package Type
PE-65835	Pulse		
TTI 7154-R	Transpower Technologies, Inc.		
TG26-1205	HALO		

Note: More transformers will be added to this list as we take the time to evaluate these transformers.

Capacitive-Coupling the Receiver to the Line

Figure 9, presents a recommended approach that the user to employ when capacitive-coupling the Receive Section to the line.

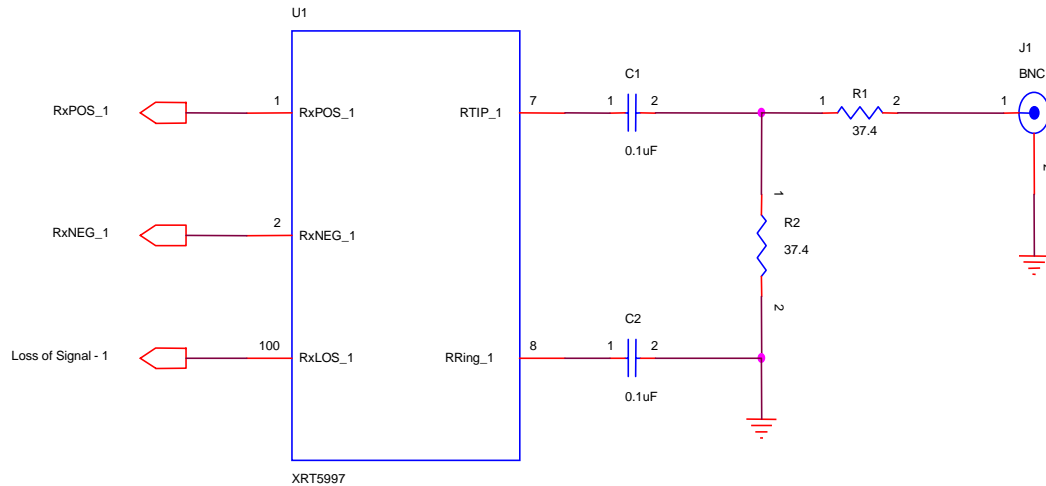


Figure 9. Recommended Schematic for Interfacing the Receive Sections of the XRT5997 Device to the Line for 75Ω Applications (Capacitive-Coupling)

2.2 The “Receive Equalizer” Block

After a given Channel (within the XRT5997 device) has received the incoming line signal, via the RTIP_x and RRing_x input pins, the first block that this signal will pass through is the Receive Equalizer block.

As the line signal is transmitted from a given “Transmitting” terminal, the pulse shapes (at that location) are basically “square”. Hence, these pulses consist of a combination of “low” and “high” frequency Fourier components. As this line signal travels from the “transmitting terminal” (via the coaxial cable or twisted pair) to the receiving terminal, it will be subjected to “frequency-dependent” loss. In other words, the higher frequency components of the signal will be subjected to a greater amount of attenuation than the lower

frequency components. If this line signal travels over reasonably long cable lengths, then the shape of the pulses (which were originally square) will be distorted and with inter-symbol interference increases.

The purpose of this block is to equalize the incoming distorted signal, due to cable loss. In essence, the Receive Equalizer block accomplishes this by subjecting the received line signal to “frequency-dependent” amplification (which attempts to counter the frequency-dependent loss that the line signal has experienced). By doing this, the Receive Equalizer is attempting to restore the shape of the line signal so that the received data can be recovered reliably.

2.3 The “Peak Detector and Slicer Block

After the incoming line signal has passed through the Receive Equalizer block, it will next be routed to the “Slicer” block. The purpose of the “Slicer” block is to quantify a given bit-period (or symbol) within the incoming line signal as either a “1” or a “0”.

2.3 The “LOS Detector” block

The LOS Detector block, within each channel (of the XRT5997 device) was specifically designed to comply

with the “LOS Declaration/Clearance” requirements per ITU-T G.775. As a consequence, the channel will declare an LOS Condition, (by driving the “RxLOS” output pin “high”) if the received line signal amplitude drops to -20dB or below. Further, the channel will clear the LOS Condition if the signal amplitude rises back up to -15dB or above. Figure 10 presents an illustration that depicts the signal levels at which a given channel (within the XRT5997 device) will assert and clear LOS.

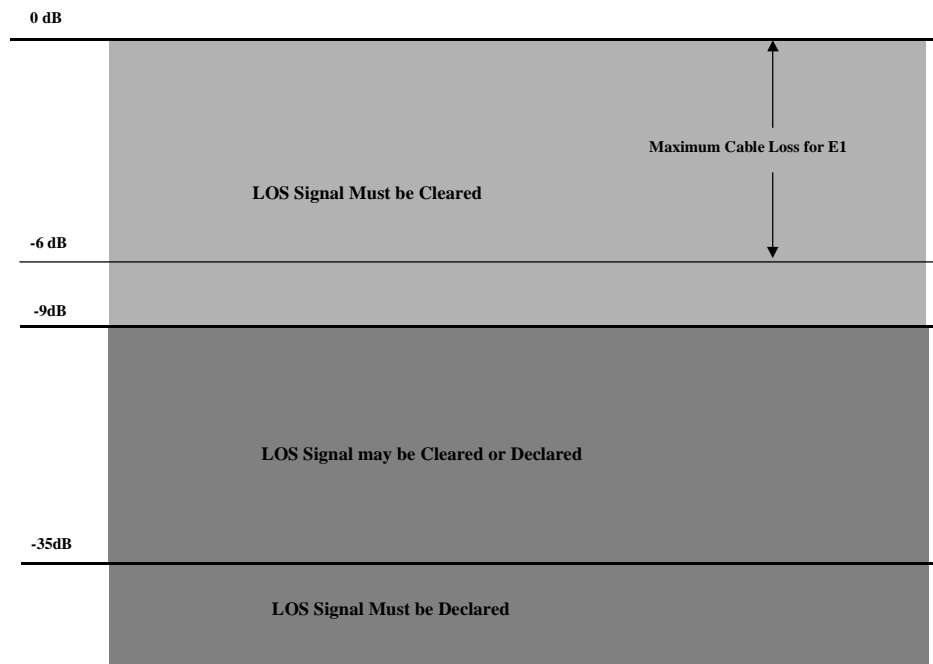


Figure 10. Illustration of the Signal Levels that the Receiver Sections (within XRT5997 device) will declare and clear LOS

Timing Requirements associated with Declaring and Clearing the LOS Indicator. The XRT5997 device was designed to meet the ITU-T G.775 specification timing requirements for declaring and clearing the LOS indicator. In particular, the XRT5997 device will declare an LOS, between 10 and 255 UI (or E1 bit-periods) after the actual time the LOS condition occurred. Further,

the XRT5997 device will clear the LOS indicator within 10 to 255 UI after restoration of the incoming line signal. Figure 11 illustrates the LOS Declaration and Clearance behavior, in response to first, the “Loss of Signal” event and then afterwards, the restoration of the signal.

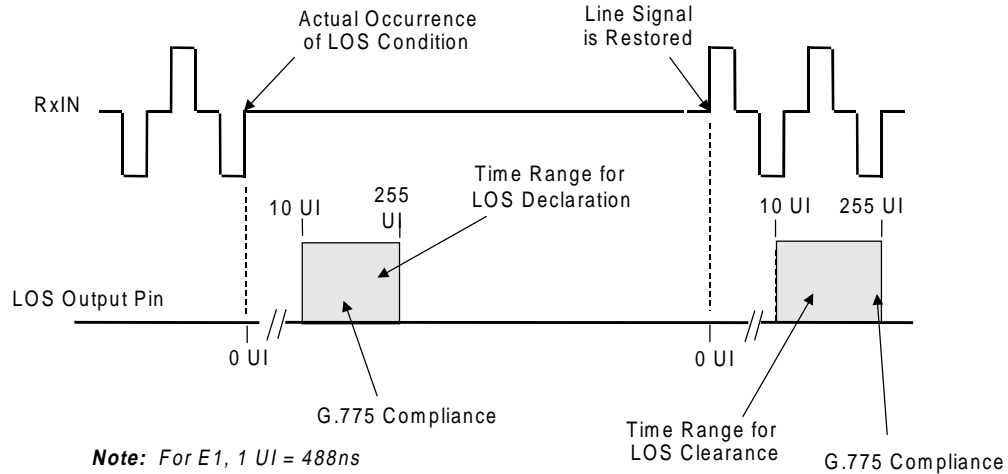


Figure 11. The Behavior of the LOS Output Indicator, in response to the Loss of Signal, and the Restoration of the Signal

2.3 The “Receive Output Interface” block

The purpose of the “Receive Output Interface” block is to interface directly with the “Receiving Terminal Equipment”. The “Receive Output Interface” block outputs the data (which has been recovered from the incoming line signal) to the “Receive Terminal Equipment” via the “RxPOS_x and RxNEG_x output pins.

If the “Receive Sections” of the XRT5997 device has received a “Positive-Polarity” pulse, via the RTIP_x and RRing_x input pins, then the Receive Output Interface will output a pulse via the “RxPOS_x” output pins.

Similarly, if the “Receive Sections” of the XRT5997 device has received a “Negative-Polarity” pulse, via the RTIP_x and RRing_x input pins, then the Receive Output Interface will output a pulse via the “RxNEG_x” output pins.

Note: The “Receive Output Interface” block does not supply a recovered clock. This device is intended to be used in those applications, where the “Clock Recovery” circuit is realized in an ASIC solution.

3.0 Shutting off the Transmitter

Each channel (within the XRT5997 device) permits the user to shut off the “Transmit Driver” within their respective “Transmit Section”. This feature can come in handy for system redundancy design considerations or during diagnostic testing. The user can activate this feature by either of the following ways.

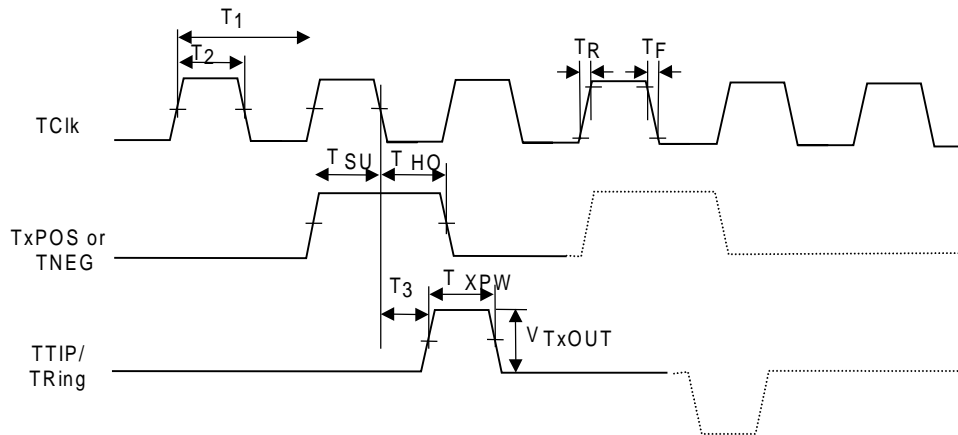
Method 1:

Connect the Transmit Data input pins (e.g., TxPOS_x and TxNEG_x) to a logic “1”; or allow them to float. (These input pins have an internal “pull-up” resistor).

Method 2:

Connect the “TxClk_x” input pin to a logic “0” (e.g., GND) and continue to apply data via the TxPOS_x and TxNEG_x input pins.

NRZ Mode (Clock Mode)



RZ Mode (None-Clock Mode)

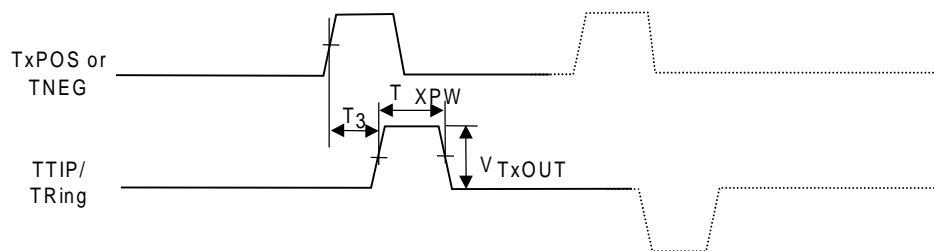


Figure 12. Transmit Timing Diagram

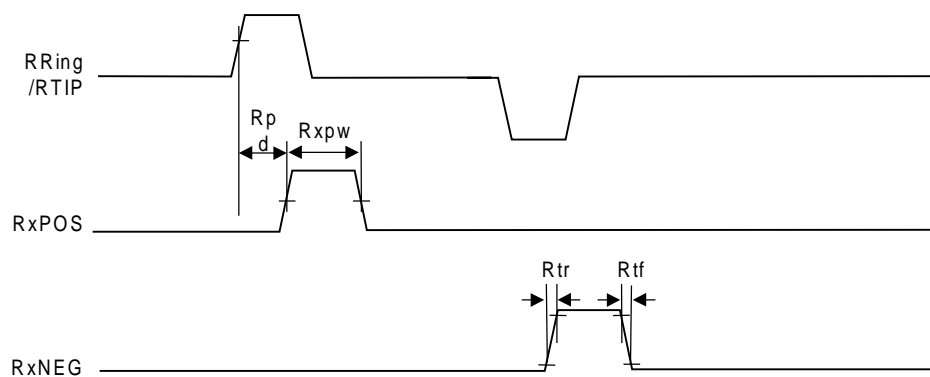


Figure 13. Receive Timing Diagram

APPLICATION INFORMATION

Figures 14, 15 and 16, provide example schematics on how to interface Channel 1 of the XRT5997 device to the line, under the following conditions.

- Receiver is Transformer-coupled to a 75Ω unbalanced line.
- Receiver is Transformer-coupled to a 120Ω balanced line.
- Receiver is Capacitive-coupled to a 75Ω unbalanced line.

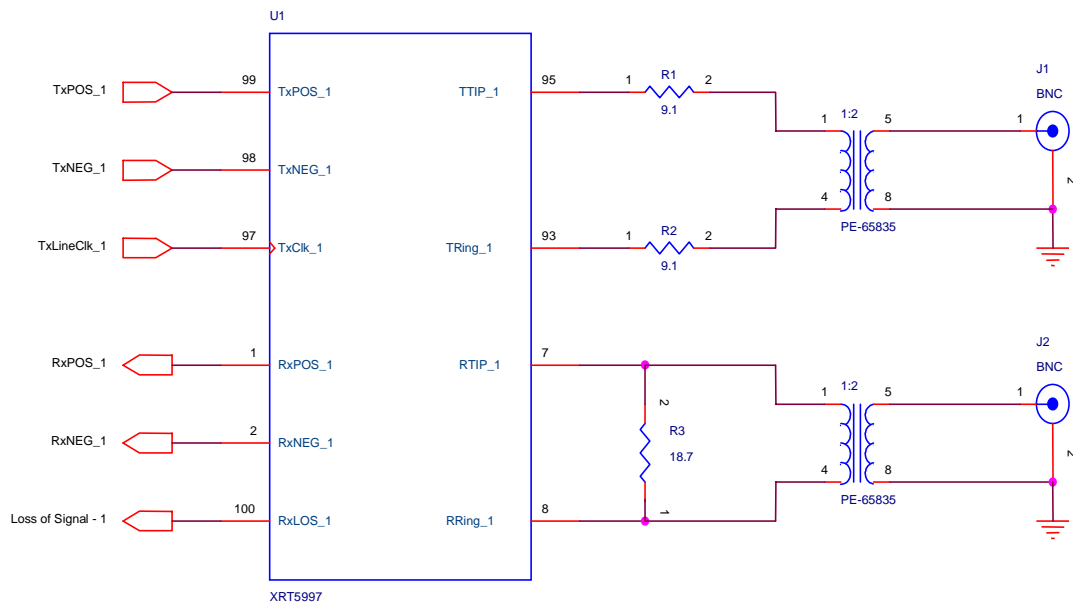


Figure 14. Illustration on how to interface Channel 1 (of the XRT5997 Device) to the Line (Receiver is Transformer-coupled to a 75Ω unbalanced line)

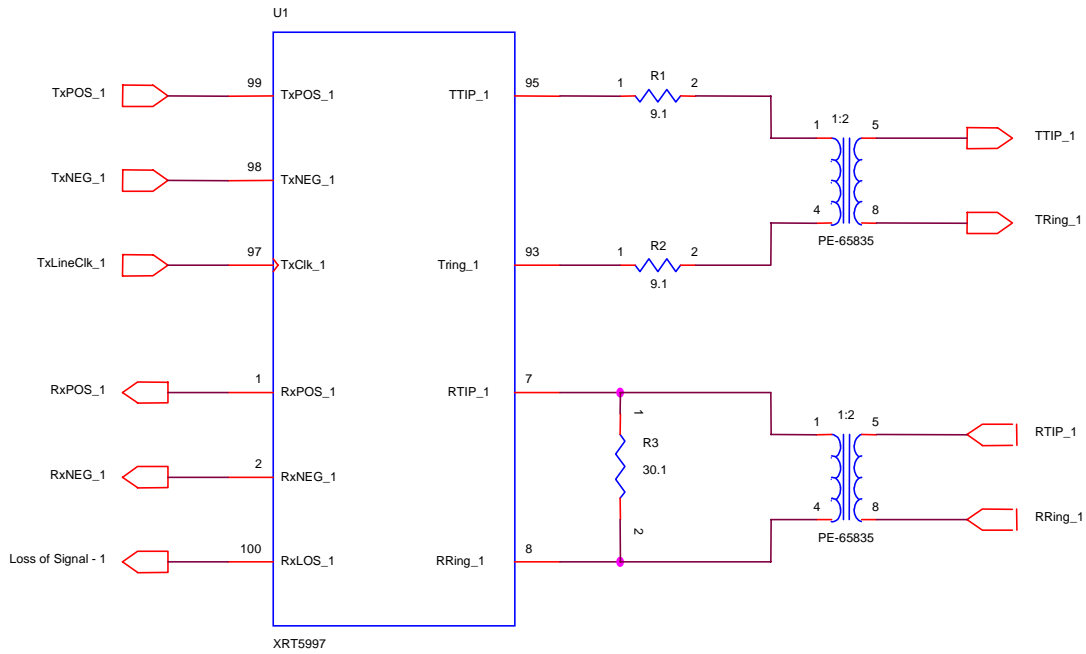


Figure 15, Illustration on how to interface Channel 1 (of the XRT5997 Device) to the Line (Receiver is Transformer-coupled to a 120Ω balanced line)

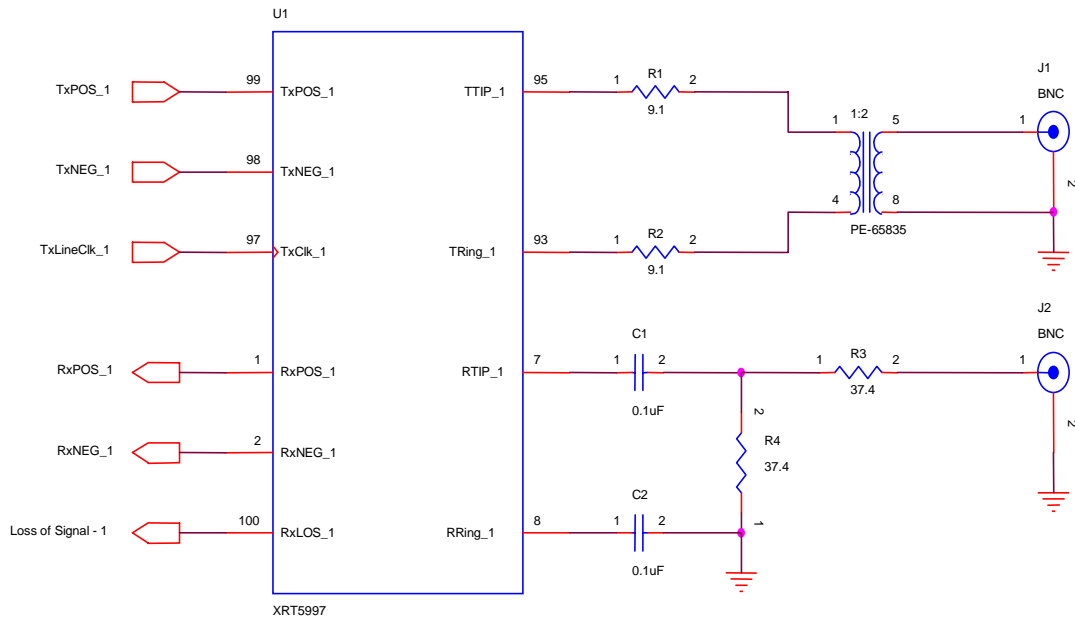
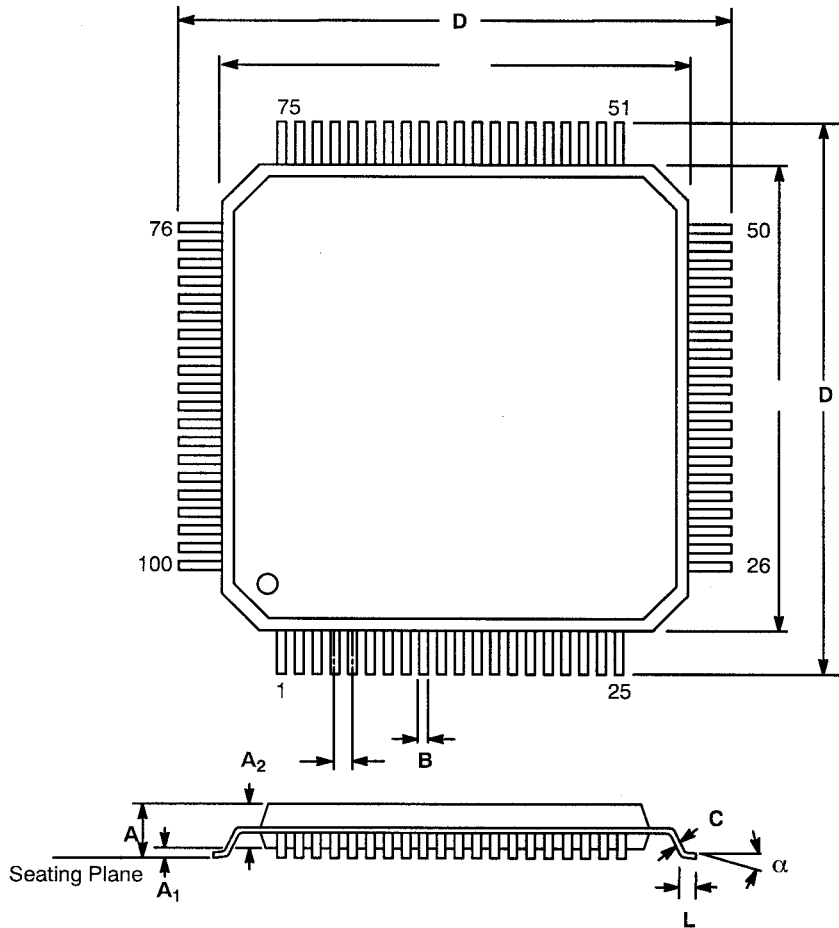


Figure 16. Illustration on how to interface Channel 1 (of the XRT5997 Device) to the Line (Receiver is Capacitive-coupled to a 75Ω unbalanced line)

100 LEAD THIN QUAD FLAT PACK (14 x 14 x 1.4 mm, TQFP)

Rev. 2.00



SYMBOL	INCHES		MILLIMETERS	
	MIN	MAX	MIN	MAX
A	0.055	0.063	1.40	1.60
A ₁	0.002	0.006	0.05	0.15
A ₂	0.053	0.057	1.35	1.45
B	0.007	0.011	0.17	0.27
C	0.004	0.008	0.09	0.20
D	0.622	0.638	15.80	16.20
D ₁	0.547	0.555	13.90	14.10
e	0.020 BSC		0.50 BSC	
L	0.018	0.030	0.45	0.75
α	0°	7°	0°	7°

Note: The control dimension is the millimeter column

Notes

Notes

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