TC1710

RS-422, RS-485 (2/4 WIRE)
FIBER OPTIC MODEM
(with Optional Dual Optics)

User's Manual

MODEL: _____

S/N: _____

DATE: _____

Notice!

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Chapter 1 - Overview

Description

The TC1710 RS-485 is an economical and dependable fiber optic modem with RS-485 interface (same as RS-422 with DB25 connector). It is available in either rack mount or stand alone versions; the rack mount version can be converted to the stand alone version with the addition of a sheet metal box. The TC1710 can communicate at distances up to 4 km using Multimode optics and up to 80 km using Single Mode optics. TC1710's design utilizes advanced FPGA (Field Programmable Gate Array) technology to increase reliability and flexibility.

Electrical Specifications

Interface:	RS-485 Async
Data Rates:	Up to 10Mbps
Connector:	DB25 Female DCE

Theory of Two and Four-Wire RS-485 Operation

Figure 1. Two-Wire RS-485 Logic Diagram

Figure 2. Four-Wire RS-485 Logic Diagram

Two-wire RS-485 is a half-duplex operation, which means transmit and receive operations take turns; they do not function concurrently. From the user's point-of-view, the channel is in receiving mode when no data is transmitted from the remote unit. (See Figure 1).

Four-wire RS-485 is a full-duplex operation, which means transmit and receive operations function concurrently. From the user's point-of-view, both channels are in the receiving or transmitting mode at all times. (See fFgure 2).

The RS-485 Driver/Receiver transition time is determined by four internal DIP switches (internal SW1) on the TC1710. The local unit's RS-485 transceiver changes to transmit (Tx) mode upon receiving the first bit of data from the remote unit. The transition time is the amount of time before the local unit's RS-485 transceiver will revert to the high-impedance receiver mode after the last bit is received from the remote unit. The RS-485 transition time should be set according to Table 1 on page 6.

RS-485 Pin Connections

For Two-wire RS-485 interfaces, pins 3(-) & 16(+) are input/outputs.

Figure 3. Two-wire RS-485 Connection/Logic Diagram

For RS-422 and RS-485 Four-wire interfaces, pins 2(-) & 14(+) are inputs while pins 3(-) & 16(+) are outputs.

Figure 4. Four-wire RS-422/RS-485 Connection/Logic Diagram

LEDs, DIP Switches and Connectors

Connector for optional secondary optic link   Connector for primary optic link

⑦   ⑥

TxB   RxB   **TC1710**   TxA   RxA
SYNC/ASYNC
FIBER OPTIC MODEM

TxD   RxD
RTS   CTS
CD   CD
TxClk   RxClk

Rx-A   ALARM
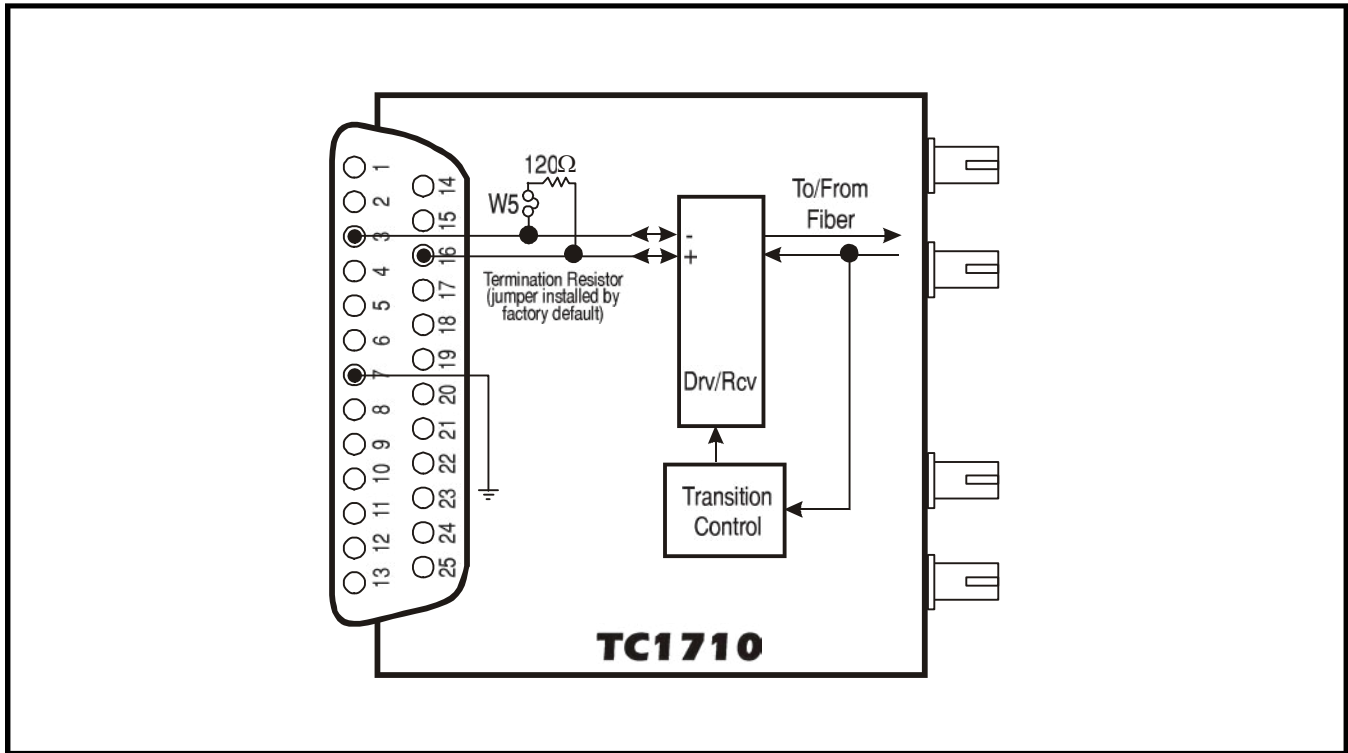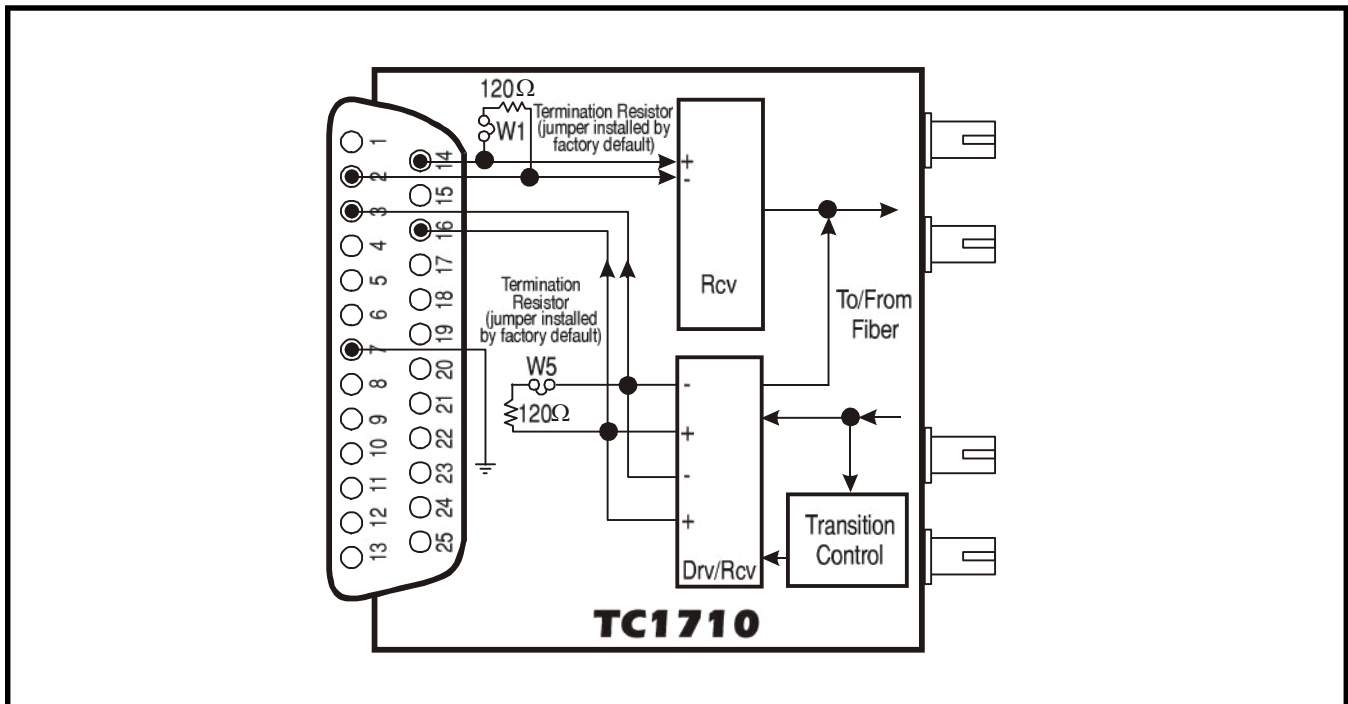Rx-B   PWRA
USE-B   PWRB
DTE   Vcc

TCCOMM.COM
Made in U.S.A.

RMTLB   DIS ALM
LOCLB   SLAVE-CLK

④

status for received electrical signals
(from remote unit):
RD- "received data" ("TD")
CTS- "clear to send"("RTS"
CD- "carrier detect" ("CD")
RCLK- "received clock" ("TxClk")

RS-232
Only

③

⑤

Status for electrical signal from
local user's device:
TxD- "transmit data"
RTS- "request to send"
CD- "carrier detect"
TxClk- "transmit clock"

RS-232
Only

Switches to initiate ("down" position)
following tests and function:
RMTLB- turn on remote unit's loopback
LOCLB- turn on local electrical interface's loopback
SLAVE-CLK - Turns on Slave Clock mode: (RT=ST)
DISALM- disable alarm buzzer and relay

RS-232 and
RS-422/
RS-485
(4 Wire)
Only

①

Alarm Indicator, Power Status &
Operating Voltage Status
Alarm (red):
    off - normal operation
    solid- major alarm condition (optic input lost)
    flash- remote loopback activated by remote unit
PWR A: DC power supply from PWR A jack
PWR B: DC power supply from PWR B jack
Vcc: +5 VDC operating voltage power supply

②

received optic signal status
& DTE indicator
RxA:
  solid- optic received "OK" from primary side ("A" side)
  flash- optic signal lost
RxB:
  solid- optic received "OK" from secondary side ("B" side)
  flash- optic signal lost or "B" side is not enabled
USE-B:
  solid- secondary optic signal is being used due to
       primary optic signal lost
  off- secondary optic receiver is not enabled or primary
      optic signal is being used.
DTE:
  the electrical signal interface at the rear panel
  (DB25 female connector) is a "DTE" interface

NOTE 1: The SLAVE-CLK DIP switch on the front panel is only used for RS-232 and RS-422 electrical interfaces.

NOTE 2:
SLAVE-CLK Switch 3: - DTE it is not used.
                - DCE when it is "on" (down position), it turns "on" the Slave-clock mode: (RT=ST).
                         when it is "off" (up position), it turns "on" the Internal clock mode: (ST=Internal clock) see table 1.

Function of Sw3

Pins:
12
15

Sw3

Internal clock
"off" (up position)

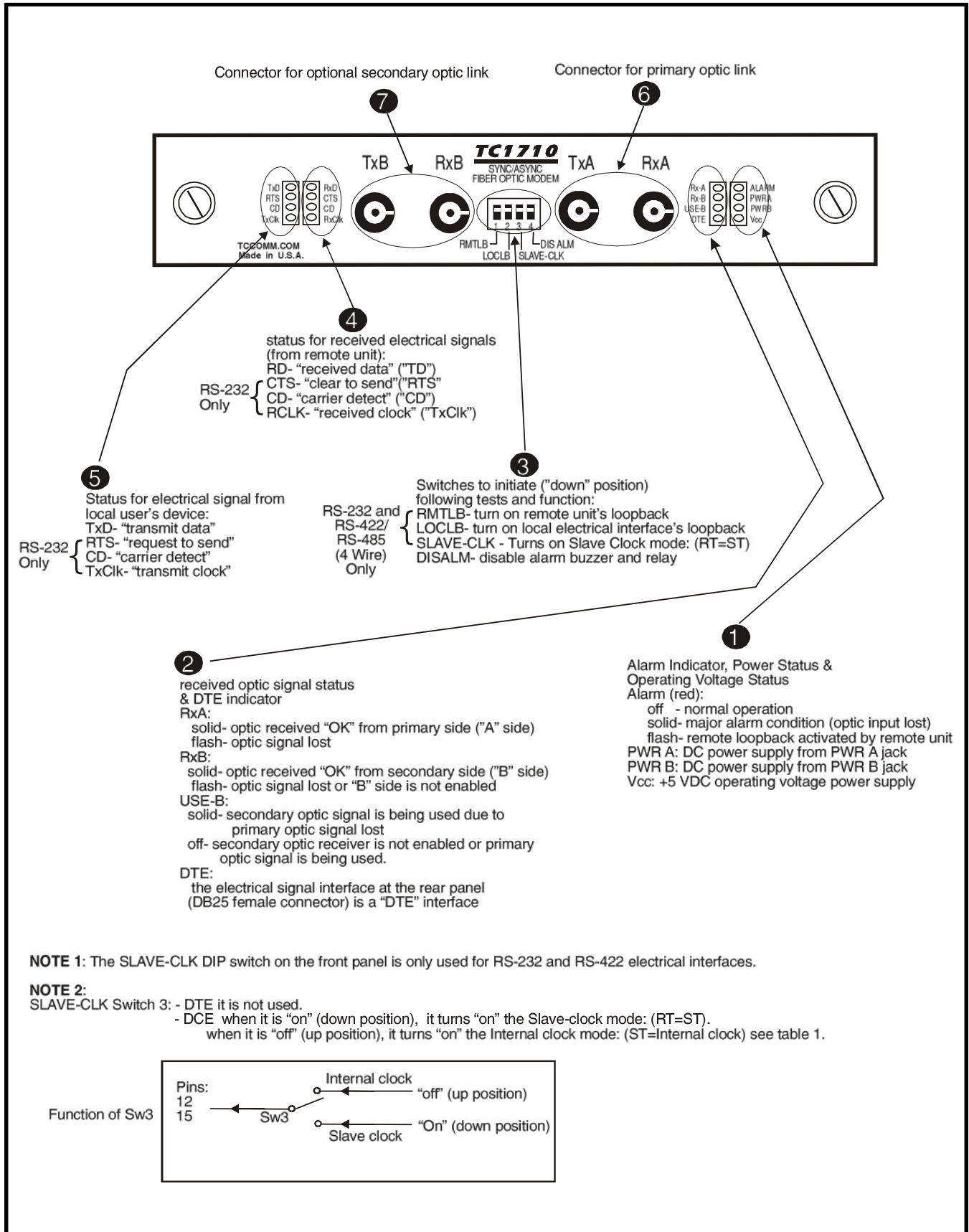Slave clock
"On" (down position)
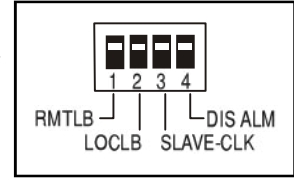
Figure 5. TC1710's Front Panel

DIP Switch Functions

For troubleshooting purpose, user can conduct remote loopback and local loopback test. TC1710 also has a built-in signal generator for user to validate fiber optic link. There are two groups of DIP switches: one at the front panel, the other one is located at the center of the PC board.

Front Panel Switches

There are four DIP switches located at the front panel. Usually, they are very useful during installation or troubleshooting. They are described as follows:

(*Note*: Remote loop back, Local loop back, and Internal clock generator tests, are only used for RS-232 and RS-422/RS485 four wire, electrical interfaces.)

DIP #1: Remote loop back. This switch (DIP #1) initiates the Remote loop back function. The composite optic signal is received from optic "RxA" and decoded, then looped back to optic "TxA."

DIP #2: Local loop back (for diagnostic use). When DIP #2 is pressed down, an electrical signal loop is created, the input electrical signal is converted to the TTL level and looped back.

DIP #3: Internal clock generator "off" when DIP #3 is in the up(off) position. When switched to the down ("on") position, the received clock signal (from the remote side) is also used as an internal clock signal and is transmitted to the user's equipment.

DIP #4: Disable dry contact alarm.

These functions can be initiated from one of four DIP switches accessible from front panel. Under normal operation, all the switches should be set in "UP" position.

SW1 Internal PCB Switches for RS-485 Transition Timer Setup

There are other eight DIP switches located at the PC board and can not be accessed from front panel. These switches are usually only used during installation.

SW1-1: Enable signal generators. This switch initiates the built-in Signal Generator function. The unit will generate a visual signal to verify optic link.

SW1-2: Configure TC1710's interface as a DTE/DCE. Not Used, set to Off position.
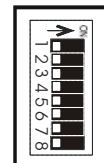
SW1-3: Enable RxB.

SW1-4: Sync/Async. For RS-485, it must be set to Async (On) position.

Note: When DIP Switches SW1-5 through SW1-8 are Off, the unit is set for RS-422. Otherwise, the unit is set for an RS-485 application, and a baud rate can be selected according to the following table.

For Oscillator: 8.192Mhz

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
SW1-5:		x		x		x		x		x		x		x		x
SW1-6:			x	x			x	x			x	x			x	x
SW1-7:					x	x	x	x					x	x	x	x
SW1-8:									x	x	x	x	x	x	x	x
RS-422		8k	9.6k	16k	19.2k	32k	38.4k	56k	64k	128k	256k	512k	1.024M	2.048M	4.096M	5 - 10M

Internal SW1

Legend: **X = ON**

This table shows the Internal Clock speed when the TC1710 is DCE, on DB25 pin 15 & 12.

Table 1. Settings for the RS-485 Transition Timer (Internal SW1)

RS-485 Transition Timer Setup

Table 1 provides setup information for configuring the SW1 Internal DIP switches for an RS-485 application. To use the table, determine the baud rate of your application and set SW5, SW6, SW7, & SW8 accordingly. For example, if you know the async data baud rate of your application is 10Khz, then set SW5 & SW6 to the right (On) position and SW7 & SW8 to the left (Off) position (on each unit). You may also want to try the 5K or 25K settings for a 9600 baud rate as a test to make sure you have the correct data rate (sometimes the best results come from trial and error). For RS-232 and RS-422 interfaces, these four switches should be kept in the Left (Off) position.

RS-422 & RS-485 Termination Resistor

A termination resistor is usually necessary for RS-422 and RS-485 applications. Without proper termination, the error rate of data transmission may be high due to an "echo" effect on the electrical connection. With the addition of a termination resistor at the beginning or end of the electrical bus, this echo effect is greatly reduced. The termination resistors are 100 to 130 ohm resistors located inside the TC1710. Two jumpers, identified as board locations "JP2" & "JP3," control the termination resistance on each unit. "JP3" controls the resistance for the unit's receiver, while "JP2" controls the transmitter's resistance. Proper line termination is usually accomplished by leaving the "JP3" jumper intact at both ends of the link. There is no termination resistor required for RS-232 applications.

Optical Specifications

The following measurements are based on Async data rates of up to 10Mbps.

Transmitter: LED/ELED; typical Launch Power: -19dBm* (850/1310nm Multimode, @62.5/125μm)
-16dBm* (1310/1550nm Single Mode, @9/125μm)

Receiver: PIN Diode; typical Sensitivity: -34dBm* (850/1310nm Multimode, @62.5/125μm)
-36dBm* (1310/1550nm Single Mode, @9/125μm)

Loss Budget: 850/1310nm MM, @62.5/125μm: 15dB
1310/1550nm SM, @9/125μm: 20dB

Distance: 850nm Multimode, @62.5/125μm: up to 3km distance*
1310nm Multimode, @62.5/125μm: up to 4km distance*
1310nm Single Mode, @9/125μm: up to 50km distance*
1550nm Single Mode, @9/125μm: up to 80km distance*

Launch power, sensitivity and distance are listed for reference only. These numbers may vary.
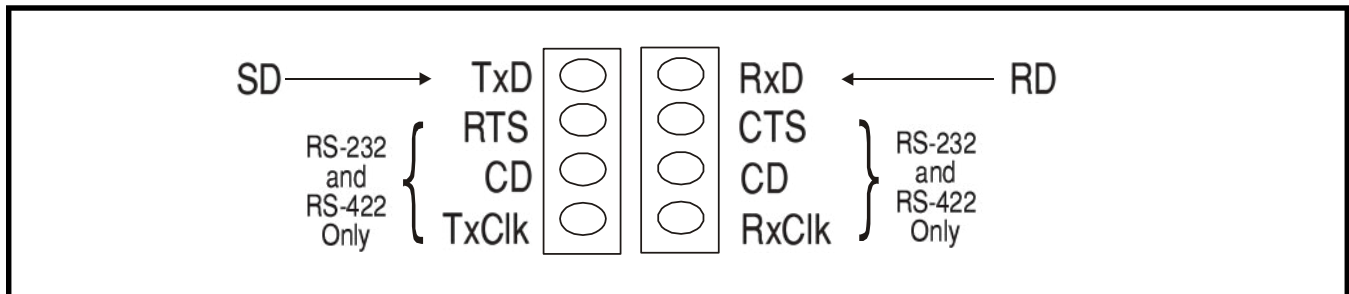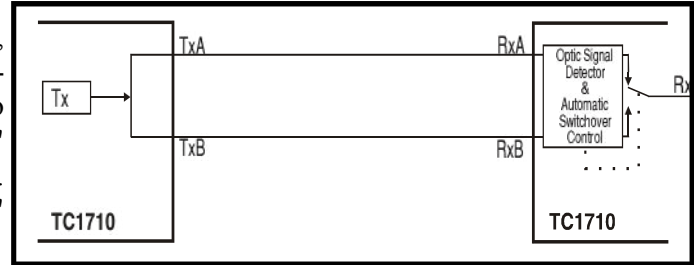
RS-485 Signal Cross Reference

Figure 6. TC1710's Signal Cross Reference
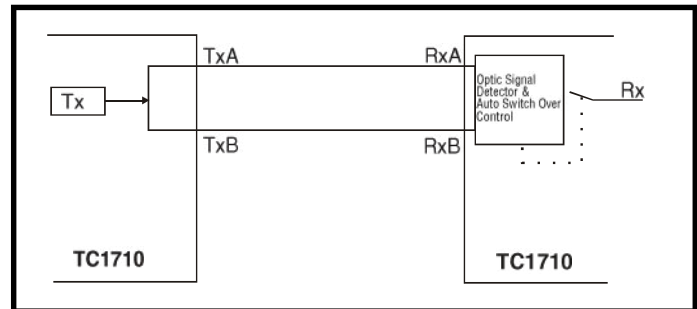
Optical Redundancy (optional)

If optic redundancy was ordered with the unit, figure below applies to its operation. Optic redundancy is used to prevent the loss of data transmission in the event an optic cable, transmitter, or receiver is broken or degraded. Should this occur, the secondary optic link & receiver "B" is enabled automatically, thereby preserving the integrity of the communication. In the meantime, the "Alarm" LED will flash and the buzzer will sound to indicate a cable breakage.

When the unit is equipped with optic redundancy, the optic transmitter "TxA" and "TxB" both transmit the same signal to the remote unit. It is up to the remote unit to decide whether "RxA" or "RxB" should be used as the valid incoming optic signal. By default, "RxA" is the primary receiver; "RxB" is the stand by backup.

Dry Contact Alarm Relay

A terminal block connector at the rear panel provides for the Dry Contact Alarm Relay. Normally in the OPEN position, any alarm condition will force the switch to a CLOSED position. This relay can be used in conjunction with an external device to signal an alarm condition.

Power Supply

The TC1710 consumes very low power. The input voltage is from 12V to 14V DC and current is 500mA (max). You may use an external power adapter with the following specifications: 12V DC @800mA (positive polarity at the left terminal when viewed from the rear panel).

The power plug can be connected into either power jack on the rear panel. Because the TC1710 is equipped with a built-in power redundancy feature, the "POWER A" or "POWER B" LEDs on the front panel will illuminate according to which power source the unit is drawing from. If power redundancy is utilized, both LEDs will light.

For units with the -48V DC power supply option, a DC-to-DC converter is installed inside the unit. The DC current requirement for the optional -48V DC power supply is @50mA.
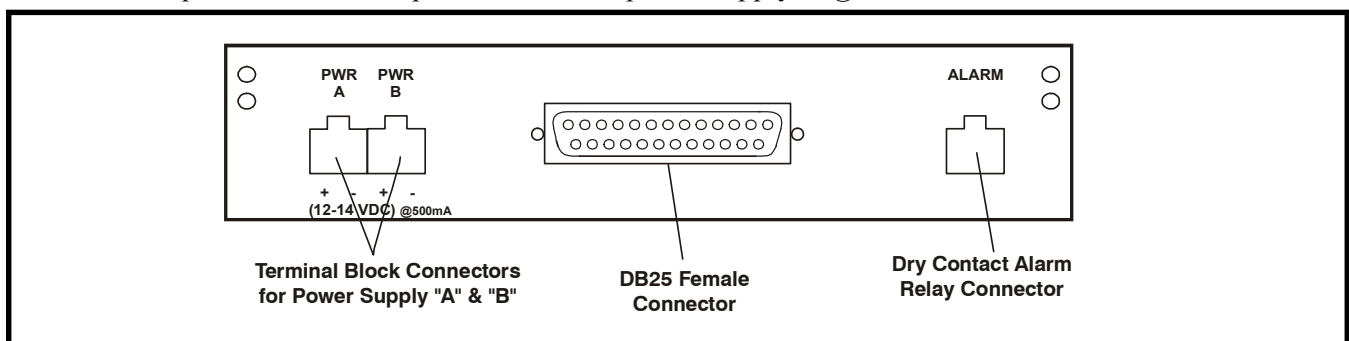
Figure 7. TC1710's Rear Panel

Chapter 2 - Installation

Unpacking the Unit

Before unpacking any equipment, inspect all shipping containers for evidence of external damage caused during transportation. The equipment should also be inspected for damage after it is removed from the container(s). Claims concerning shipping damage should be made directly to the pertinent shipping agencies. Any discrepancies should be reported immediately to the Customer Service Department at TC Communications, Inc.

Equipment Location

The TC1710 should be located in an area that provides adequate light, work space, and ventilation. Avoid locating it next to any equipment that may produce electrical interference or strong magnetic fields, such as elevator shafts, heavy duty power supplies, etc. As with any electronic equipment, keep the unit from excessive moisture, heat, vibration, metallic particles and freezing temperatures. Installation Procedure Summary

Installation Procedure Summary

The TC1710 is designed for quick and easy installation. Before installing, however, make sure all DIP switches are in the up ("Off") position and double-check the polarity at the DC power's terminal block connector. The installation procedure is as follows:

1. **Connect your DTE/DCE Device to the DB25 Connector:** Check the Pin Assignments on page 4 and verify your application's data rate. Shielded cable is recommended.

2. **Connect the optic cables:** Connect the local unit's optic "TxA" to the remote unit's optic "RxA". Connect the local unit's optic "RxA" to the remote unit's optic "TxA." (do the same for "TxB" and "RxB" on Dual Optics Models).

3. **Connect the power plug:** The plug can be connected into either power terminal "A" or "B" (check for proper polarity). The unit is equipped with power redundancy. By plugging a second power supply to the spare power terminal, power redundancy is enabled. Verify that the power "A" and/or "B" LED is illuminated.

4. **Turn "On" your device:** If your device is a DTE device, the "TxD" LED on the local unit should be illuminated, meaning the signal is being transmitted. On the remote unit, the RxD LED should be illuminated, meaning the signal is being received.

    If your device is a DCE device, the "RxD" LED on the local unit should be illuminated, meaning the signal is being received. On the remote unit, the TxD LED should be illuminated, meaning the signal is being transmitted.

5. **Check the "Rx-A" LEDs:** When a good optic signal is received, the "Rx-A" LED on the corresponding unit should illuminate. (Check "Rx-B" LED when "Optic TxB" and "Optic RxB" are in use. Dual Optics model only).
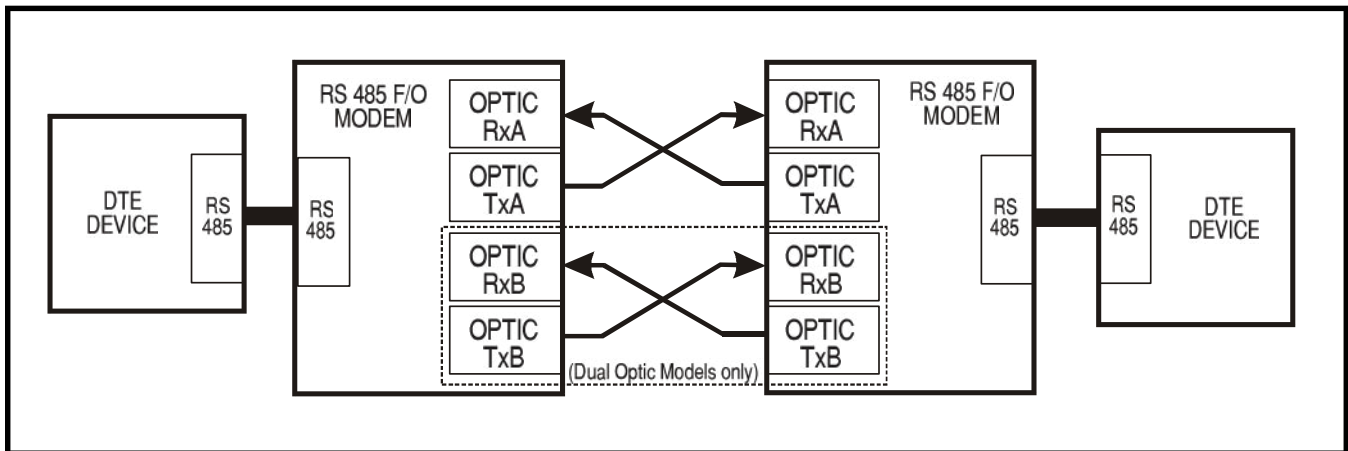
Figure 8. Typical Point-to-Point RS-485 Application

After installation is complete, it is an excellent idea to verify and record the optical cable loss. This reading will both verify the integrity of the system and provide a benchmark for future troubleshooting efforts (see Chapter 3 - Troubleshooting).

Chapter 3 - Troubleshooting

General

Typically, most problems encountered during installation are related to an improperly wired RS-485 cable or a break in the integrity of the fiber optic link (cable or connectors).

All LEDs are "Off"

If no LEDs are lit on the unit, check the DC power supply, terminal block connector plug, and/or power source. If the problem persists, contact the Technical Support Department at TC Communications, Inc.

Alarm LED

When there is an alarm condition, the red "ALARM" LED will be lit and the "RxA" LED will also flash to indicate the optic signal has been lost. The Alarm will also trigger the dry contact relay switch.

Optic Cable Types

Conventionally, fiber optic cable with yellow-colored insulation is used for single mode applications; gray or orange-colored insulated cable is for multimode use. If multimode cable is used in a single mode application, the test results could be erroneous and confusing.

Calculating the Loss on the Fiber

The fiber optic link and/or the connectors are frequently the source of communication problems. If problems are present, check the optic connectors and the integrity of the link first. Ideally, the link should be calibrated for total loss after the installation has been completed. This will accomplish two things: (1) it will verify that the total loss of the link is within the loss budget of the device and (2) it will provide a benchmark for future testing. For example, a system that has been tested as having 6dB of signal loss when installed should not suddenly test out as having a loss of 10dB. If this were the case, however, the fiber link or connector would probably be the source of the problem.

These are the reference values we use to calculate the loss on the fiber:		
Multimode 850nm	:	3 dB loss per km on 62.5/125µm cable*
Multimode 1310nm	:	2 dB loss per km on 62.5/125µm cable*
Single Mode 1310nm	:	0.5 dB loss per km on 9/125µm cable*
Single Mode 1550nm	:	0.25 dB loss per km on 9/125µm cable*

These numbers are listed for reference only. We recommend an OTDR reading be used to measure actual link loss.

RS-485 Cable Verification

1. Make sure the electrical signal connections match the pin assignments for the device (refer to page 4 and Appendix A & B for DCE/DTE user equipment pin connections). Verify signal connections by checking the status LEDs on the front panel of the TC1710. Verify that the pin signal connections match the appropriate LED responses (see Figures 3 & 4).

2. Be sure that all switches are set correctly. All the front panel DIP switches should be in up (off) position. All the "SW1 Internal DIP Switches" are generally factory configured. However, the transition timer can be user configured with SW1-5, SW1-6, SW1-7, and SW1-8, to suit the user's timing needs, refer to table 1 on page 6.

Optic Cable Verification

If the "Rx-A" LED on the front panel is flashing (or off), this is an indication that the optic signal is not being correctly received. Usually, unsecured fiber optic connectors or faulty cable are to blame. A good connection is indicated by the "Rx-A" LED on the front panel being solidly lit. This indicates that the receiving cable is correctly connected to the remote unit's optic "TxA."

On Dual Optics Models, the same applies to "RxB" and "TxB." Dual Optics Models will automatically switch to optic "RxB" if optic "RxA" is not receiving a valid signal. This automatic switchover enables the user to verify the "B" fiber connection by simply disconnecting the "A" fiber connection, thereby verifying the optical redundancy capability of the unit. (Dual Optics is an optional feature).

Chapter 4 - Bench Tests

General

It is highly recommended to conduct a bench test before actual installation. A bench test will allow the user to get familiar with all the functions and features of the TC1710 in a controlled environment. Knowledge of the TC1710's functions and features will facilitate installation and troubleshooting efforts later on.

Test Equipment Requirements

End user equipment required for testing:

1. One BERT (Bit Error Rate Tester) test set with a DB25 male adapter and appropriate interface module (match pin assignments with the diagrams on page 4).

2. Two short optical cable jumpers with appropriate connectors (ST or FC).

Pre-Installation Tests

1. Make sure the appropriate power supply accompanies the TC1710 unit (see page 8).

2. To verify that the unit functions properly, plug in only the power connector to the terminal (be sure to observe correct polarity), without having any other cable connections to the unit.

3. On the front panel, the appropriate green "Power A" or "Power B" LED should be illuminated (depending on whether you plug into the "A" or "B" terminal on the back of the unit). Both lights should be on if you utilize power redundancy (power is connected to both "A" and "B" terminals on the rear panel).

4. The "ALARM" and "Rx-A" LEDs should be flashing.

5. The "Vcc" LED should be illuminated. Please note: all other LEDs can be in a random state (flashing, solidly lit, or off) as only upon proper receipt and transmission of a signal will the TC1710 set its LEDs appropriately for normal operation.

Bench Test With Built-In Signal Generator

The TC1710 has built-in signal generator to simulate a polling device's incoming electrical signal. The built -in signal generator is a pulse signal indicated by blinking LED. The flash rate intentionally reduced for easy visual confirmation.

1. Setup the bench test as shown in figure 9.

2. At the local TC1710 unit, turn on the "SIG-GEN" by sliding SW1-1 (switch 1 of the "SW1 Internal DIP Switch") to the right (on) position.

2a. For "Async" units(SW1-4: enable "on"): Turn on the "RMTLB" by pressing down the DIP switches #1 of "Front Panel DIP Switches" on the Local TC1710. The "TxD," "RTS," and "CD," LEDs on the local TC1710 should start blinking. Verify that the remote unit's "RxD," "CTS," and "CD" LEDs also blink, indicating receipt of the remote unit's simulated response.

2b. For "Sync" units(SW1-4: disable "off"): Turn on the "RMTLB" by pressing down the DIP switches #1 of "Front Panel DIP Switches" on the Local TC1710. The "TxD," and "TxCLK," LEDs on the local TC1710 should start blinking. Verify that the remote unit's "RxD," and "RxCLK" LEDs also blink, indicating receipt of the remote unit's simulated response.

Figure 9. Signal Generator Bench Test Connection Diagram

Chapter 5 - Component Placement

DRY CONTACT ALARM

DB25 female connector for electrical signal connection

(12 - 14VDC) @ 500mA
POWER B   POWER A

TERMINAL BLOCK CONNECTORS

fuses

INTERFACE MODULE

JP2

SW1

F1

F2

FPGA chip

FPGA configuration EEPROM

U4

Trim-pot to adjust optic launch power:
Clockwise to increase optic power;
counter-clockwise to decrease optic power.

SW2

Optic "TxB" (optional)   Optic "RxB (optional)   Optic "TxA"   Optic "RxA"

SW1 Internal DIP Switches

Used to configure TC1710 as a DCE (left) or DTE (right) device, enable secondary optic receiver, enable signal generator & select internal clock rate.
SW1-1: enable signal generators
SW1-2: configure TC1710's interface to DTE (see text for details)
SW1-3: enable RxB
SW1-4: Sync/Async. For RS-485, it must be set to Async "On"position.

Legend: **X = ON**

This table shows the Internal Clock speed when the TC1710 is DCE, on DB25 pin 15 & 12.

For Oscillator: 8.192Mhz

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
SW1-5:		X		X		X		X		X		X		X		X
SW1-6:			X	X			X	X			X	X			X	X
SW1-7:					X	X	X	X					X	X	X	X
SW1-8:									X	X	X	X	X	X	X	X
RS-422	8k	9.6k	16k	19.2k	32k	38.4k	56k	64k	128k	256k	512k	1.024M	2.048M	4.096M	5 - 10M

Figure 10.   Component Locations on TC1710's Internal PCB (with optional Dual Optics)

Chapter 6 - Specifications

Data Rates

Asynchronous .... Up to 10Mbps

Optical

Transmitter .... LED/ELED
Receiver .... Pin Diode
Wavelength .... 850nm/1310nm Multimode
.... 1310/1550nm Single Mode
Connector .... ST* (optional FC)
Loss Budget** .... 15dB Multimode 850nm/1310nm @62.5/125μm
.... 20dB Single Mode 1310/1550nm @9/125μm

Electrical

Interface RS-422, RS-485
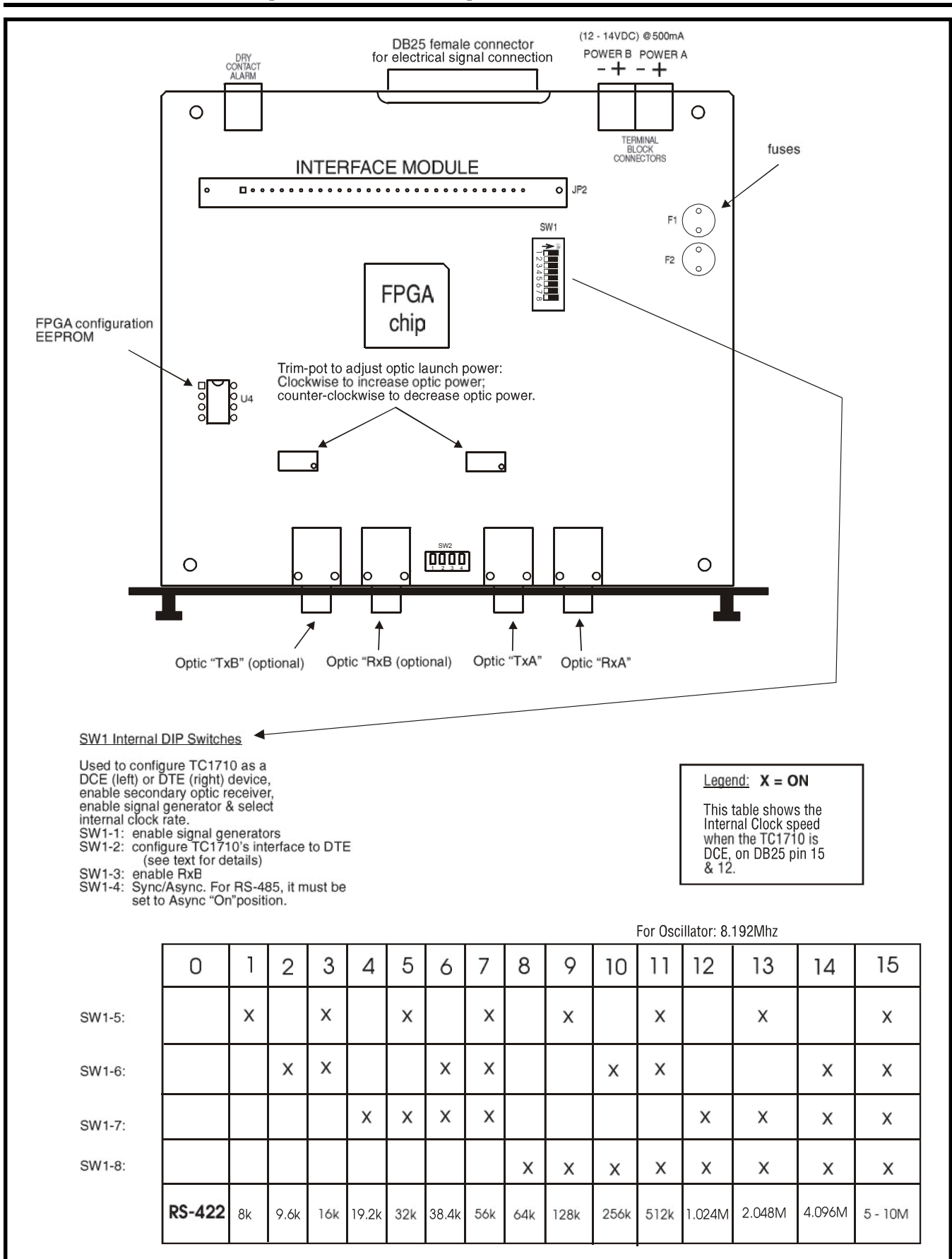Connector .... DB25 Female

System

Bit Error Rate .... 1 in 10^9 or better

Indicators

System status .... ALARM, PWR A, PWR B, Vcc, Rx-A, Rx-B, USE-B, DTE
Electrical Signal Status .... RxD, TxD
Optic Signal Status .... TxA, RxB (for Dual Optics, TxB and RxB)

Power Source

Standard .... 12V to 14VDC @500mA (typical)
Optional .... 24VDC, 48VDC, or 115/230VAC with an external power cube

Temperature

Operating .... -10°C to 50°C
.... Hi-Temp Version 1 (optional) -20°C to 70°C
.... Hi-Temp Version 2 (optional) -40°C to 80°C
Storage .... -40°C to 90°C
Humidity .... 95% non-condensing

Physical (Rackmount Card)

Height .... (17.7 cm) 7.0"
Width .... (3.2 cm) 1.25"
Depth .... (14.8 cm) 5.75"
Weight .... (192 gm) 5.44 oz

*ST is a trademark of AT&T
**Contact factory for loss budget requirements greater than 20dB (Laser version).

Appendix A

DB25 to Winchester (DTE) Adapter Cable

DB25 male to Winchester male Adapter Cable
(convert TC1705 to V.35 Winchester DTE)

	polarity	signal direction to TC1705 DCE ←	V.35 DB25 male pin #	V.35 DCE Winchester male (34 pin)
Send Data	A	→	2	R
	B		14	T
Receive Data	A	←	3	P
	B		16	S
Terminal Timing (DTE source)	A	→	24	V
	B		11	X
Receive Timing	A	←	17	U
	B		9	W
Transmit Timing (DCE source) (INT clock or Slave clock)	A	Not Applicable	15	Y
	B		12	AA
signal ground			7	B
frame ground			1	A

DB25 MALE

V.35 WINCHESTER MALE

ROUTER

TC1705 V.35   DCE

DCE

Figure 11.   DB25 to V.35 Winchester DTE Pin Assignments

Appendix B

DB25 to Winchester (DCE) Adapter Cable

DB25 male to Winchester male Adapter Cable
(convert TC1705 to V.35 Winchester DCE)

	polarity	signal direction to TC1705 DCE ←	V.35 DB25 male pin #	V.35 DCE Winchester male (34 pin)
Send Data	A	←	2	P
	B		14	S
Receive Data	A	→	3	R
	B		16	T
Terminal Timing (DTE source)	A	←	24	U
	B		11	W
Receive Timing	A	→	17	V
	B		9	X
Transmit Timing (DCE source) (INT clock or Slave clock)	A	→	15	Y
	B		12	AA
signal ground			7	B
frame ground			1	A

DB25 MALE

V.35 WINCHESTER MALE

ROUTER

TC1705 V.35   DCE

DTE

Figure 12. DB25 to V.35 Winchester DCE Pin Assignments

Appendix C

Return Policy

To return a product, you must first obtain a Return Material Authorization number from the Customer Service Department. If the product's warranty has expired, you will need to provide a purchase order to authorize the repair. When returning a product for a suspected failure, please provide a description of the problem and any results of diagnostic tests that have been conducted.

Warranty

Damages by lightning or power surges are not covered under this warranty.

All products manufactured by TC Communications, Inc. come with a five year (beginning 1-1-02) warranty. TC Communications, Inc. warrants to the Buyer that all goods sold will perform in accordance with the applicable data sheets, drawings or written specifications. It also warrants that, at the time of sale, the goods will be free from defects in material or workmanship. This warranty shall apply for a period of five years from the date of shipment, unless goods have been subject to misuse, neglect, altered or destroyed serial number labels, accidents (damages caused in whole or in part to accident, lightning, power surge, floods, fires, earthquakes, natural disasters, or Acts of God.), improper installation or maintenance, or alteration or repair by anyone other than Seller or its authorized representative.

Buyer should notify TC Communications, Inc. promptly in writing of any claim based upon warranty, and TC Communications, Inc., at its option, may first inspect such goods at the premises of the Buyer, or may give written authorization to Buyer to return the goods to TC Communications, Inc., transportation charges prepaid, for examination by TC Communications, Inc. Buyer shall bear the risk of loss until all goods authorized to be returned are delivered to TC Communications, Inc. TC Communications, Inc. shall not be liable for any inspection, packing or labor costs in connection with the return of goods.

In the event that TC Communications, Inc. breaches its obligation of warranty, the sole and exclusive remedy of the Buyer is limited to replacement, repair or credit of the purchase price, at TC Communications, Inc.'s option.

To return a product, you must first obtain a Return Material Authorization (RMA) number and RMA form from the Customer Service Department. If the product's warranty has expired, you will need to provide a purchase order to authorize the repair. When returning a product for a suspected failure, please fill out RMA form provided with a description of the problem(s) and any results of diagnostic tests that have been conducted. The shipping expense to TC Communications should be prepaid. The product should be properly packaged and insured. After the product is repaired, TC Communications will ship the product back to the shipper at TC's cost to U.S. domestic destinations. (Foreign customers are responsible for all shipping costs, duties and taxes [both ways]. We will reject any packages with airway bill indicating TC communications is responsible for Duties and Taxes. To avoid Customs Duties and Taxes, please include proper documents indicating the product(s) are returned for repair/retest).

Limitation of Liability

1. In no event shall the total liablility of TC Communications, Inc. to purchaser and/or end user for all damages including but not limited to compensatory, consequential and punitive damages, exceed the total amount paid to TC Communications, Inc. by purchaser for the goods from which the claim arose, in no event shall TC Communications, Inc. be responsible for indirect and consequential damages.

Continue on next page.

Limitation of Liability (Cont.)

2.   In no event shall liability attached to TC Communications, Inc. unless notice in writing is given to TC Communications, Inc. within ten days of the occurrence of the event giving rise to such claim.

3.   TC Communications, Inc. shall not be responsible for delays or non-deliveries directly or indirectly resulting from or contributed to by foreign or domestic embargoes, seizure, fire, flood, explosion, strike, act of God, vandalism, insurrection, riot, war, or the adoption or enactment of any law, ordinances, regulation, or ruling or order or any other cause beyond the control of TC Communications, Inc.

4.   TC Communications, Inc. shall not be responsible for loss or damage in transit and any claims for such loss or damage shall be filed by the purchaser with the carrier.