TC8116

8 or 16 CHANNEL
ASYNC & SYNC
FIBER OPTIC MULTIPLEXER

User's Manual

MODEL: _____

S/N: _____

DATE: _____

Notice!

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TC COMMUNICATIONS
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- ❒ **LEDs for "Tx" & "Rx" (to monitor each channel's electrical signal status)**
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- ❒ **LEDs for "PWR A," "PWR B," "Vcc," & "ALM" (to monitor each unit's power supply and alarm condition status)**
- ❒ **DIP Switches for Local Loopback, Optic Remote Loopback, Signal Generator & more (for diagnostics)**
- ❒ **Rack Mount or Stand Alone**

Description

The **TC8116** is a time division multiplexer which can multiplex up to 16 channels of signals. It can be factory or user configured to several different variations.

The typical unit has one main PC board (A board) with two interface SIMM modules. The main PC board has eight RJ-11 ports: each RJ-11 port has one duplex data channel. The interface SIMM module is field interchangeable. The extension PC board (B board) also has eight RJ-11 ports for additional channels 9 through 16 (for 8 channel units, these additional ports are not used).

The **TC8116 multi-interface model** offers several different interchangeable interfaces, such as RS-232, RS-422, RS-485, TTL, Dry Contact Relay, Analog or Intercom. It can be upgraded or reconfigured to virtually any configuration; simply contact the factory should the need arise.

The TC8116 is based on modern FPGA (Field Programmable Gate Array) technology. As a result, it benefits users by enabling optimum flexibility, low current consumption, high reliability and maximum MTBFs (100,000 hours or better). Each unit has a built-in Signal Generator, Polarity Inverter switch, and Local & Remote Loopback features to ease installation and facilitate troubleshooting procedures. Fiber optic connectors are ST (optional FC); electrical connectors are RJ-11 Female. Power is 9 to 12VDC. Optional power supplies are also available (see Chapter 5 - Specifications).

The TC8116 consists of two PC boards connected together internally by ribbon cables. Each PC board has its own DIP switches, LEDs, optic connectors and electrical signal ports. The PC board with the "A" optic connectors is referred to as the "A" board, while the board with the "B" optic connectors is referred to as the "B" board. Each board's panel is designed with multiple status monitoring features. The fiber optic signal is monitored continually so that, should an optic fault condition or cable breakage occur, the alarm will be triggered and the corresponding LEDs will indicate the type & location of the problem.

LEDs, DIP Switches & Connectors

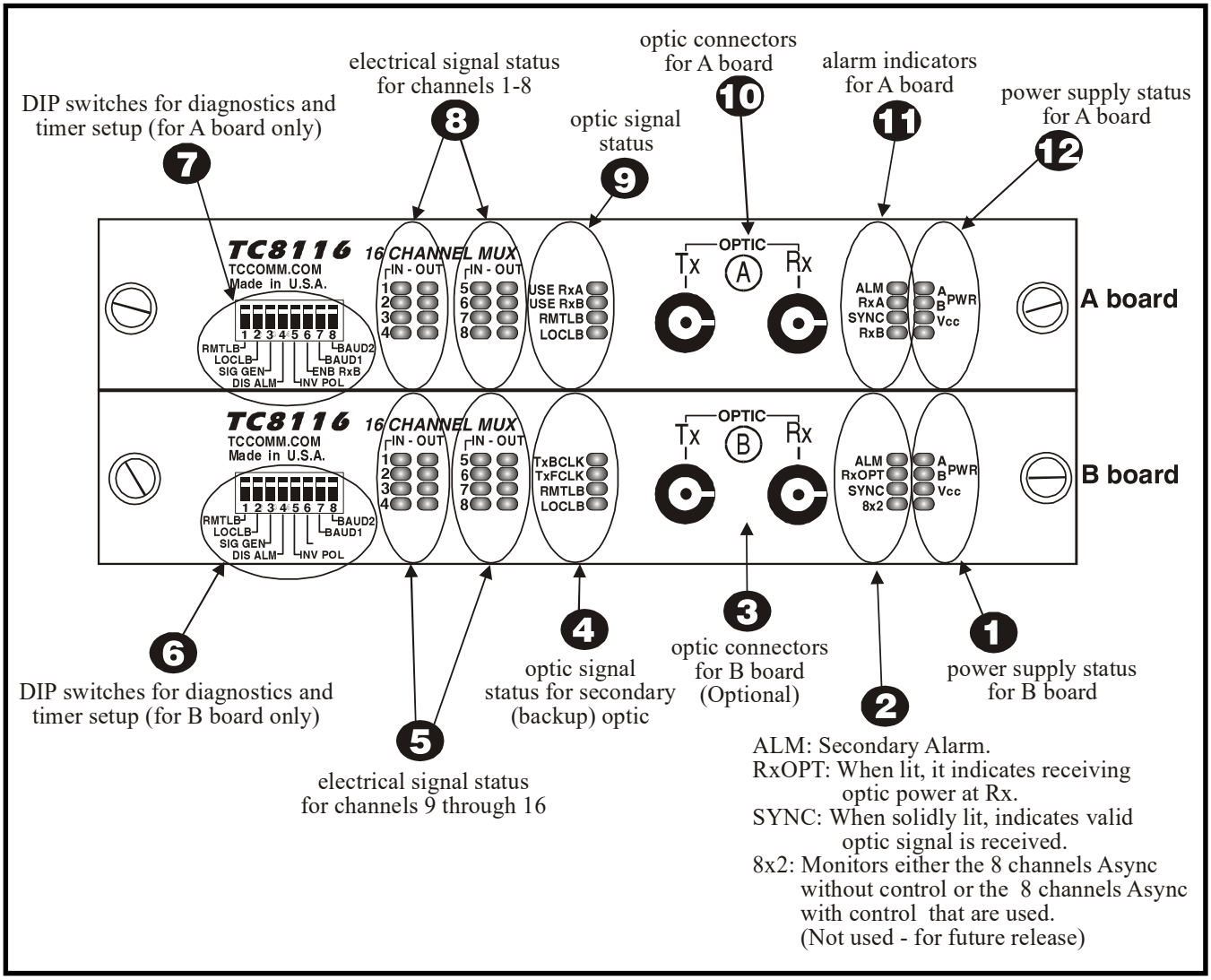


Figure 1. TC8116's Front Panel (16 Channel/Dual Optional Optic model)

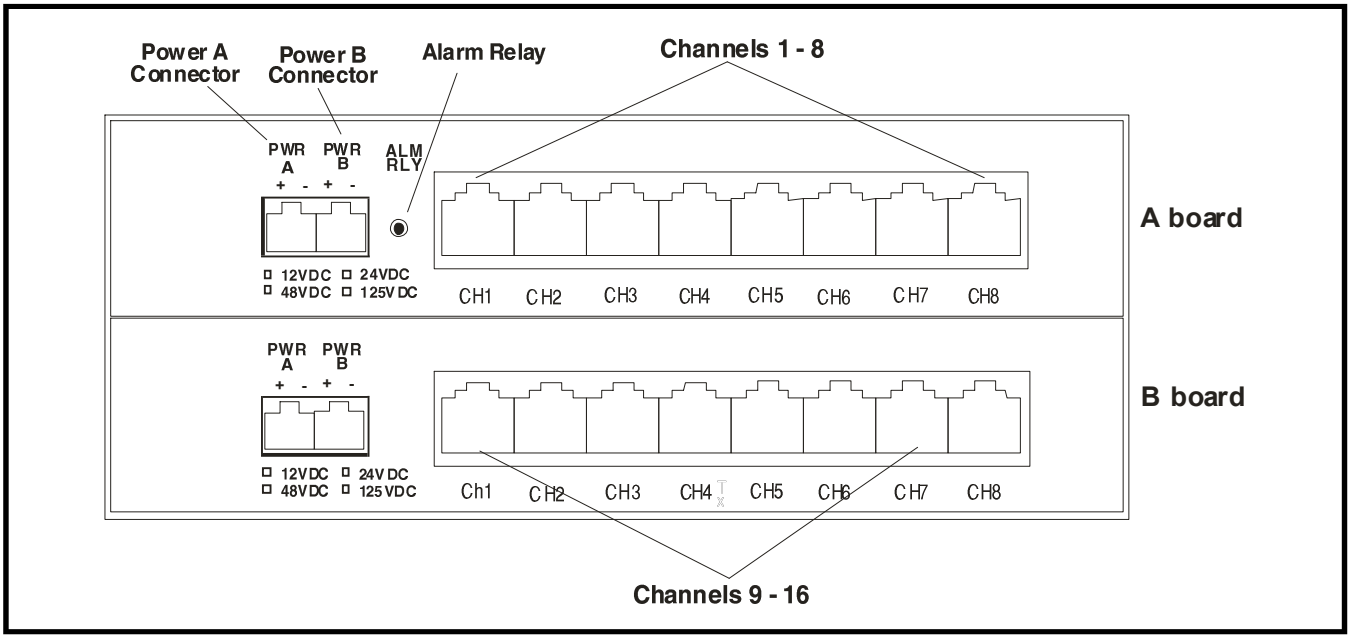
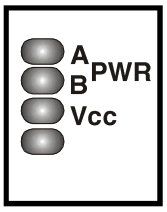


Figure 2. TC8116's Rear Panel

LED Functions

The TC8116's front panel LED indicators are divided into four categories: Power, Alarms, Optic Signal and Electrical Signal status. By understanding the functions of the LEDs & DIP switches, the user can ease installation and troubleshooting.

Groups 1 & 12



Power supply and voltage indicators. These LEDs should always be lit whenever power is connected (with the exception of either "PWR A" or "PWR B" when the power redundancy feature is not utilized.

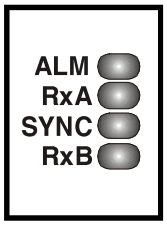
PWR A : +12V DC power supply from DC power A input.

PWR B : +12V DC power supply from DC power B input.

Vcc : +5V DC operating voltage derived from "PWR A" and/or "PWR B."

Not Used.

Group 11



General alarm indicators. In a fault condition, the "ALM" LED will flash and one or more other alarm LED will be unlit.

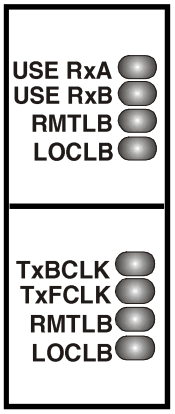
ALM: (flashing) One of the "Tx" or "Rx" optic signals has been lost.

RxA: (unlit) The optic signal at "RxA" has been lost or is degraded.

SYNC: When lit, it means a valid data packet is recognized at the active receiver.

RxB: (unlit) The optic signal at "RxB" has been lost or is degraded.

Groups 4 & 9



Optic status indicators.

USE RxA: (A board) When lit, it means the optic signal received at "RxA" is above the sensitivity threshold and "RxA" is the active receiver. It does not necessarily mean a valid signal is received.

USE RxB: (A board) Same as "USE RxA," but for the backup link. When lit, it usually means there is a problem with the "A" fiber link and the backup link is being used.

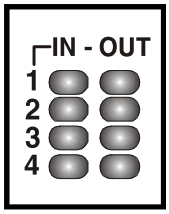
RMTLB: Loops back the electrical signal on the remote unit through fiber back to the source, see Figure 17 on page 15.

LOCLB: Loops back the electrical signal to the source.

TxBLCK: This LED indicates that the transmit bit clock is received from the base board.

TxFLCK: This LED indicates that the transmit frame clock is received from the base board.

Groups 5 & 8

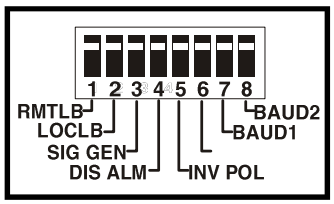


Electrical signal channel status indicators. Each RJ-11 port (at the rear panel) has two LEDs (on the front panel) showing its electrical signal status.

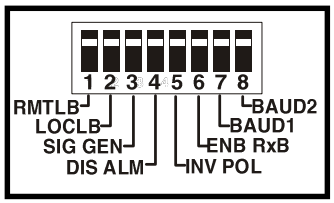
The green "OUT" LEDs indicate the electrical signal transmit status for each channel (from the local device); the green "IN" LEDs indicate the channel's receive status (from the remote device).

DIP Switch Functions

Groups 6 & 7



Note: SW6 is not used.



The DIP switch functions on the TC8116 apply individually to their respective "A" or "B" board. To activate the function, slide the appropriate switch to the On (Down or Right) position.

RMTLB: Remote Loopback. This switch (SW1) initiates the Remote Loopback function. The composite optic signal is received from optic "RxA" (or "RxB) and decoded, then looped back to optic "TxA" (or "TxB) for diagnostic testing.

LOCLB: Local Loopback. This switch (SW2) initiates the Local Loopback function. The electrical signal is received and decoded, then looped back to the transmit pins for diagnostic testing.

SIG GEN: Signal Generator. This switch (SW3) initiates the built-in signal generator function. The unit will generate a pulse signal to emulate an electrical transmission signal. By verifying the "Rx" channel LEDs on the remote unit, the user may confirm that the local unit's signal is being received.

DIS ALM: Disable Alarm. This switch (SW4) disables the alarm relay and buzzer during alarm conditions.

ENB RxB. Enables optical redundancy "B" (Optical Redundant Models Only).

INV POL: Inverse Polarity.

BAUD 1 & 2: RS-485 high impedance timer setup switches.

	RS-232 RS-422	RS-485 4.8K	RS-485 9.6K	RS-485 19.2K & Above
SW7	Off	On	Off	On
SW8	Off	Off	On	On

Figure 3. RS-485 Transition Timer Setup Table

The RJ-11 connectors are located at the rear panel of the TC8116.

RS-232 (Async & Async with Control)

For RS-232, pin 5 is the input (TxD) pin while pin 4 is the output (RxD) pin. A separate channel on each RJ-11 port is available on pin 3 and pin 2 (for Async with Control or Sync interfaces). The second channel can be used as control (or handshake) signals or Tx Clock and Rx Clock signals for RS-232 synchronous applications.

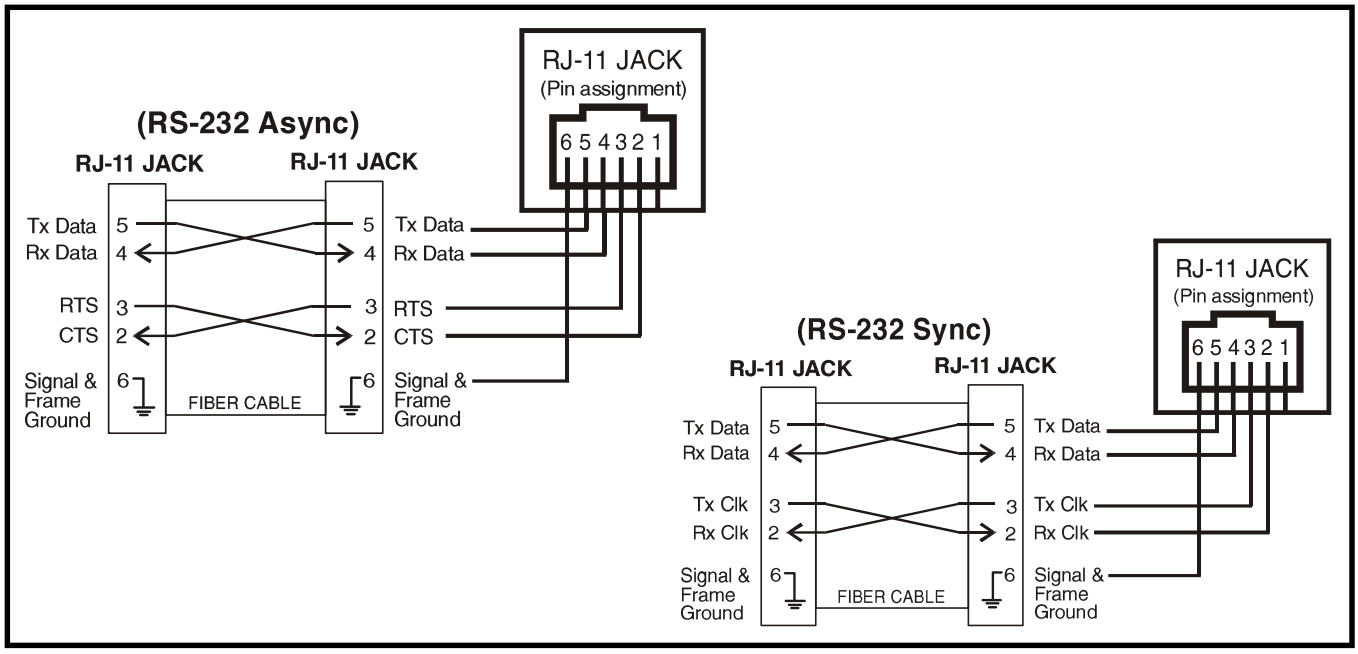


Figure 4. RS-232 Async Pin Assignments & Virtual Connection Diagram

RS-422/RS-485 Asynchronous

For RS-422 & RS-485 interfaces, pins 2 and 5 are balanced input pins. Pin 2 is the positive input (TxD+) while pin 5 is negative (TxD-).

Pins 3 and 4 are balanced output pins. Pin 3 is the positive output (RxD+) while pin 4 is negative (RxD-). Either pin 6 or pin 1 can be Signal Ground.

Only RS-422/RS-485 Async communications can be used with the TC8116 due to the limited number of pins on the RJ-11 connector.

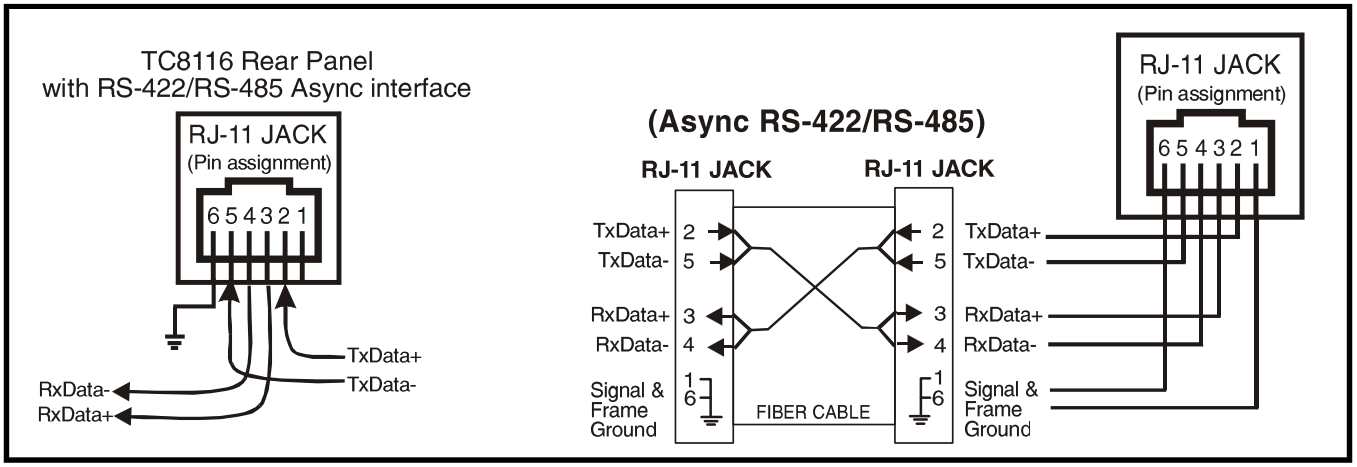


Figure 5. RS-422/RS-485 Async Pin Assignments & Virtual Connection Diagrams

RS-485 (2 wire) Electrical Signal Interface Connection & Pin Assignments

The RJ-11 connectors are located at the rear panel of the TC8116.

Two wire (Half Duplex) RS-485 Asynchronous

For two wire RS-485, use pins 3 and 4.
Either pin 6 or pin 1 can be Signal Ground.

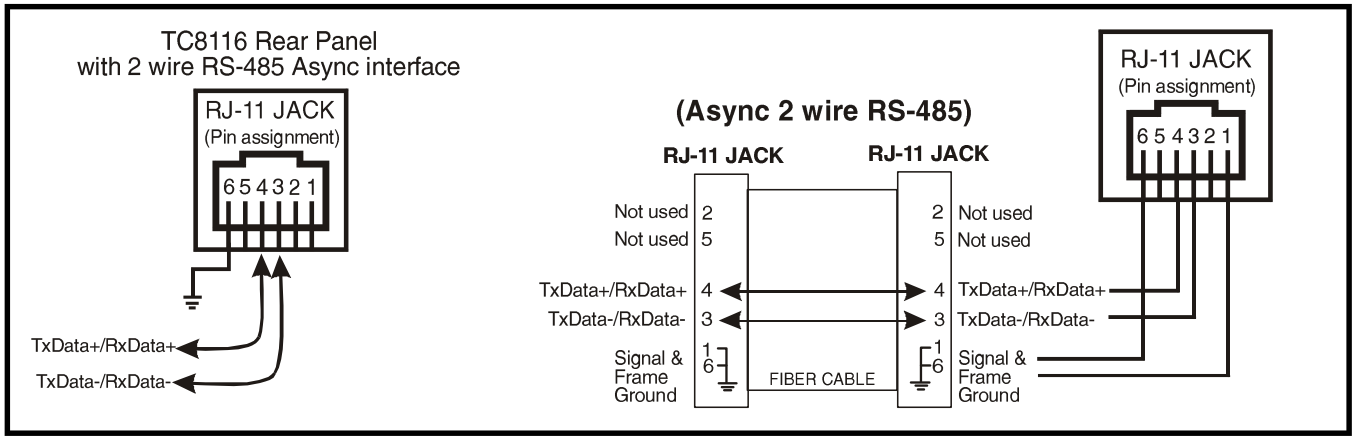


Figure 6. Two wire RS-485 Async Pin Assignments & Virtual Connection Diagrams

Intercom & Analog Interfaces

For Voice and audio channels, pin 5 is transmit TIP & pin 2 is transmit RING (the signal from the handset's mouth piece). Pin 4 is receive TIP & pin 3 is receive RING (the signal that goes to the handset's ear piece). Similarly, pin 5 on an intercom channel is MIC+ & pin 2 is MIC-, while pin 4 is SPKR- and pin 3 is SPKR+.

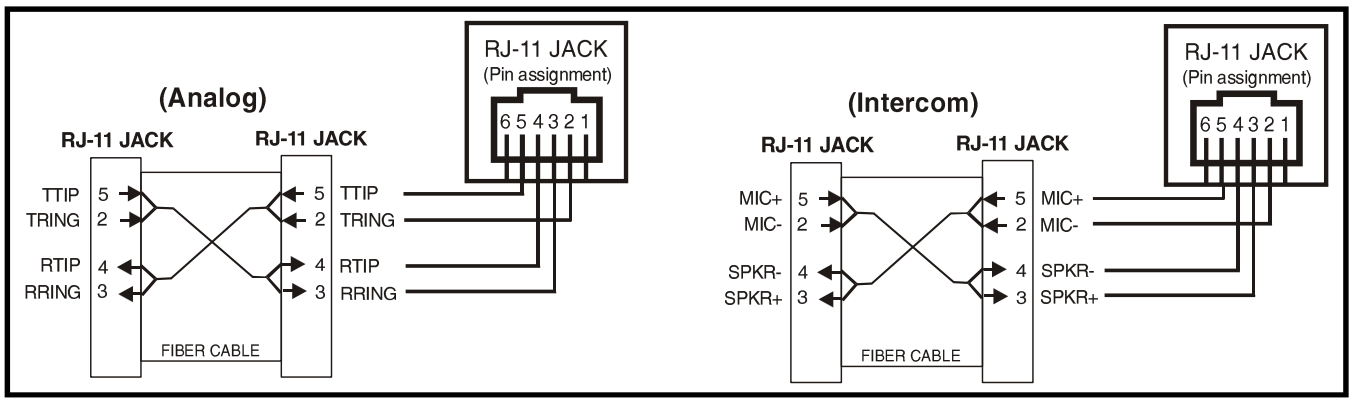


Figure 7. RJ-11 Analog and Intercom Pin Assignments & Virtual Connection Diagrams

TTL Asynchronous

Similar to the RS-232 interface, the TTL interface utilizes pin 5 for input (TxD) while pin 4 is output (RxD).

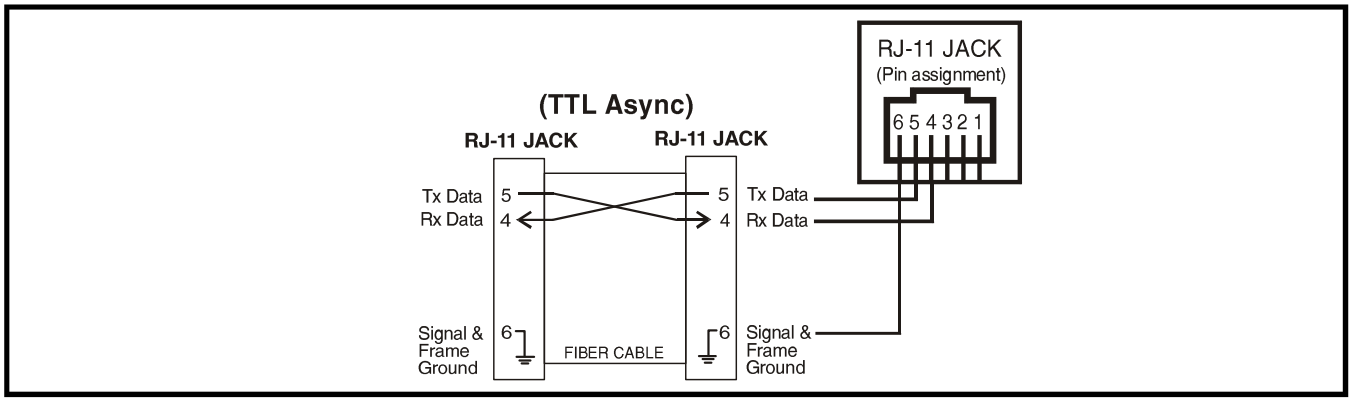


Figure 8. RJ-11 TTL Async Pin Assignments & Connection Diagram

Single Direction Dry Contact Closure Detector & Relay Switch (optional)

For dry contact closure applications, only uni-direction transmission is allowed. The transmitter side has a dry-contact closure detector as shown in the diagram below.

The receiver side has a dry-contact closure relay switch. The "close" and "open" status is controlled by a relay switch inside the TC8116. It reflects the remote detector's "on" and "off" status.

As illustrated below, when the RJ-11's pin 4 and pin 5 are closed at the transmitter side, the status is reflected at the remote receiver's side. The relay switch on the receiver's side is rated 0.5A DC switching current, with a max load rating of 10VA.

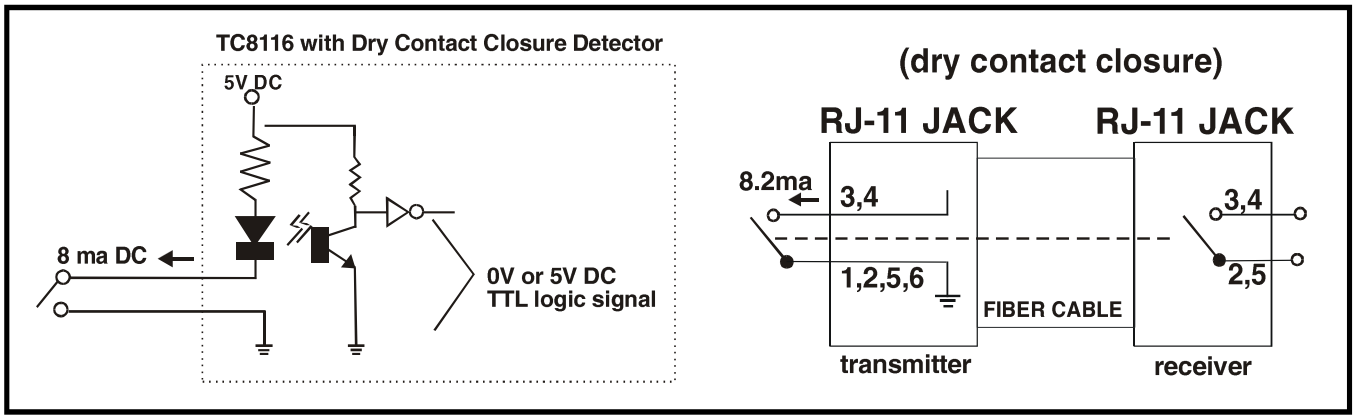


Figure 9. Single Direction Dry Contact Detector and Closure Logic Diagrams

Bi-Directional Dry Contact Closure Detector & Relay Switch (optional)

For dry contact closure applications, the TC8116 can be used as either the Closure or Detector depending on which pins are used. The transmitter side has a dry-contact closure detector as shown in the diagram below. The receiver side has a dry-contact closure relay switch. The "close" and "open" status is controlled by a relay switch inside the TC8116. It reflects the remote detector's "on" and "off" status.

The diagram below, illustrates the virtual pin connections for using the TC8116 as either a dry contact Detector (Transmitter) or a dry contact Closure (Receiver). The RJ-11's pins 4 and 5 are closed at the transmitter side, the status is reflected at the remote receiver's side RJ-11's pins 2 and 3. The relay switch on the receiver's side is rated 0.4A DC switching current, with a max load rating of 24VA.

As an option, the relay switch on the receiver's side can be rated 1.8A DC switching current, and a load rating of 108VA.

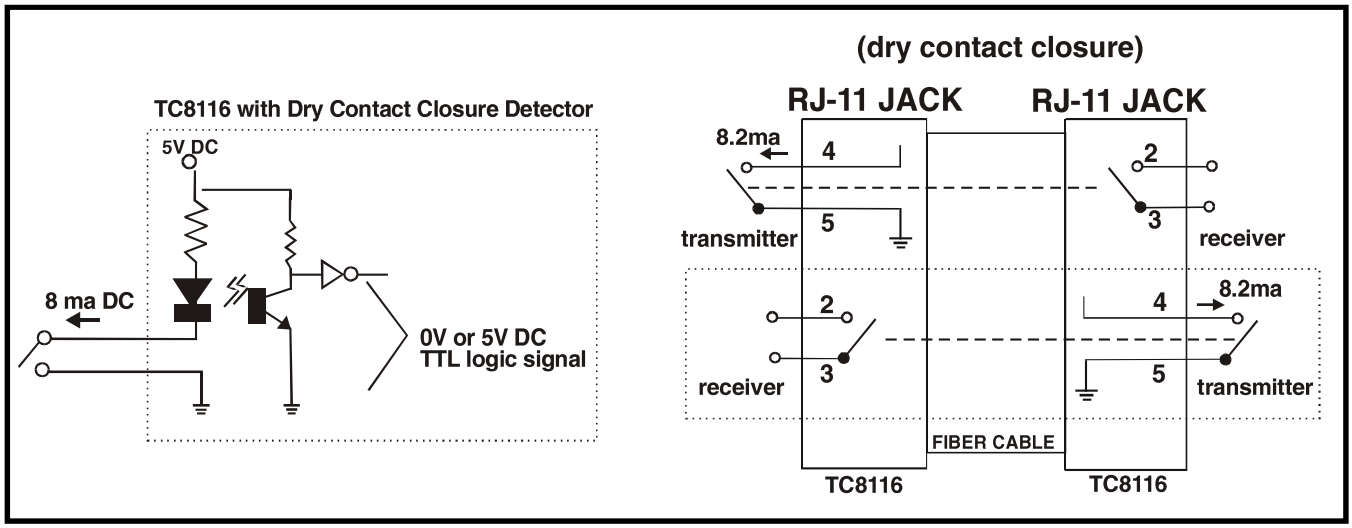


Figure 10. Bi-Directional Dry Contact Detector and Closure Logic Diagrams

RJ-11 to DB25 Female (Async) Connection Cables

The user's device can be a DCE or DTE device (which may have a DB25 male connector). The following illustrations depict the RS-232/TTL & RS-422/RS-485 wiring diagrams for constructing an RJ-11 to DB25 Female adapter cable.

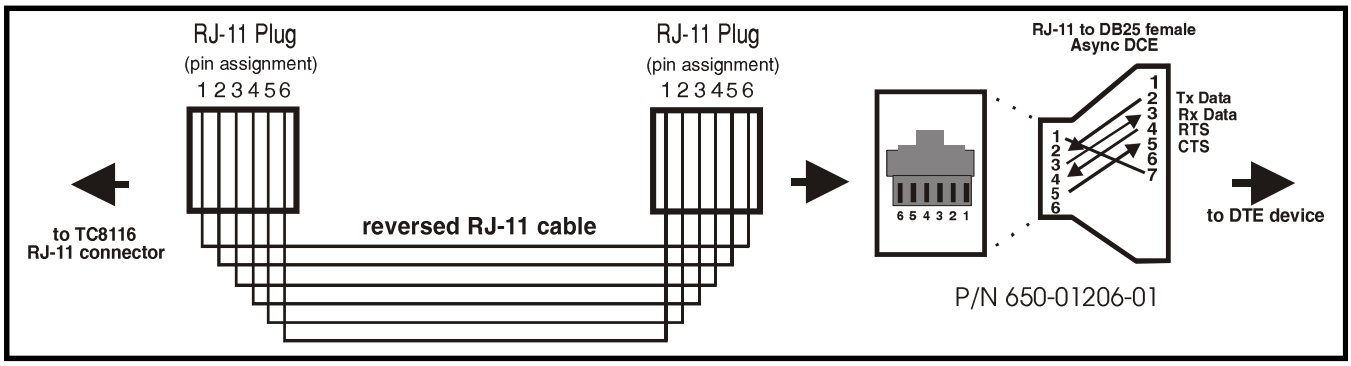


Figure 11. RJ-11 (ASYNC DCE) Pin Assignments & Connection

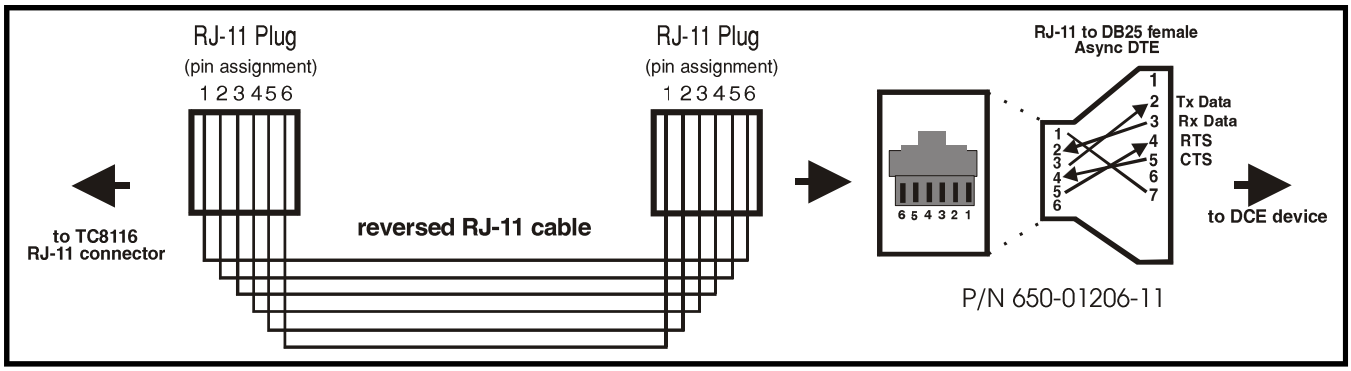


Figure 12. RJ-11 (ASYNC DTE) Pin Assignments & Connection

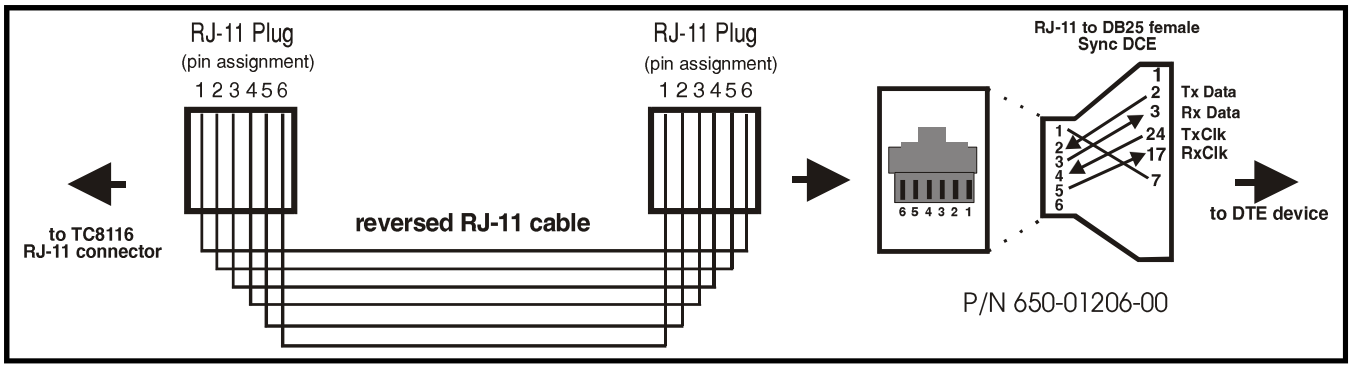


Figure 13. RJ-11 (SYNC DCE) Pin Assignments & Connection

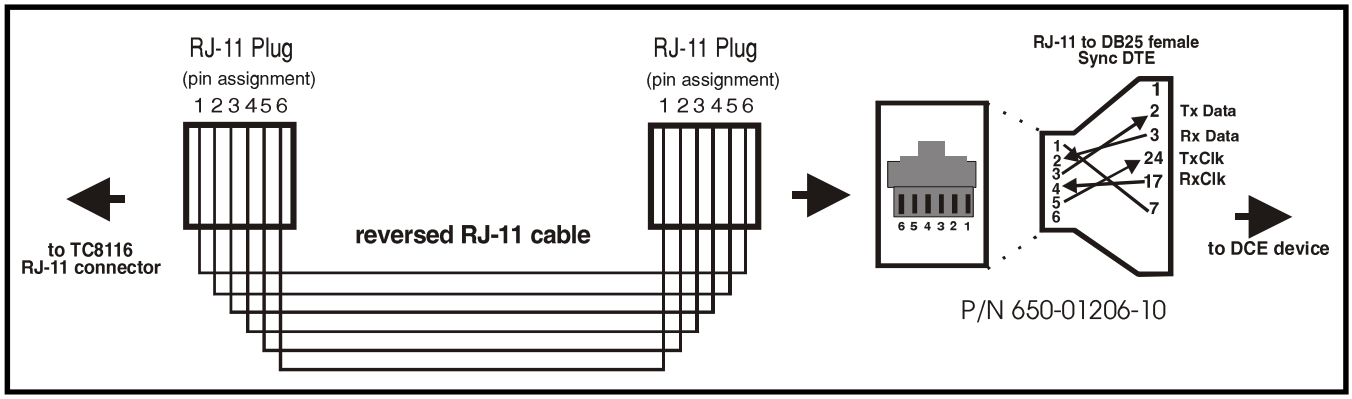


Figure 14. RJ-11 (SYNC DTE) Pin Assignments & Connection

RJ-11 to DB25 Female (Async) Connection Cables (Cont.)

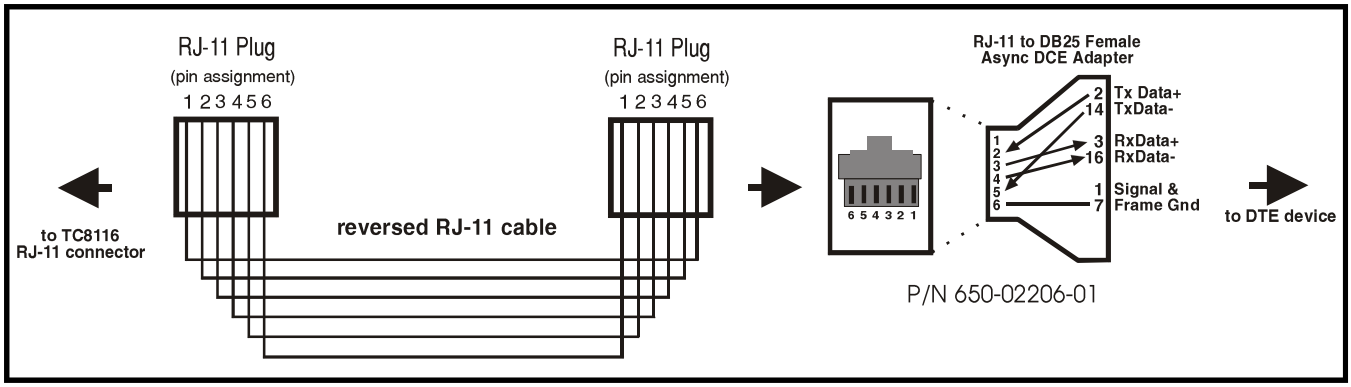


Figure 15. RJ-11 (ASYNC DCE) RS-422/RS-485 Pin Assignments & Connection

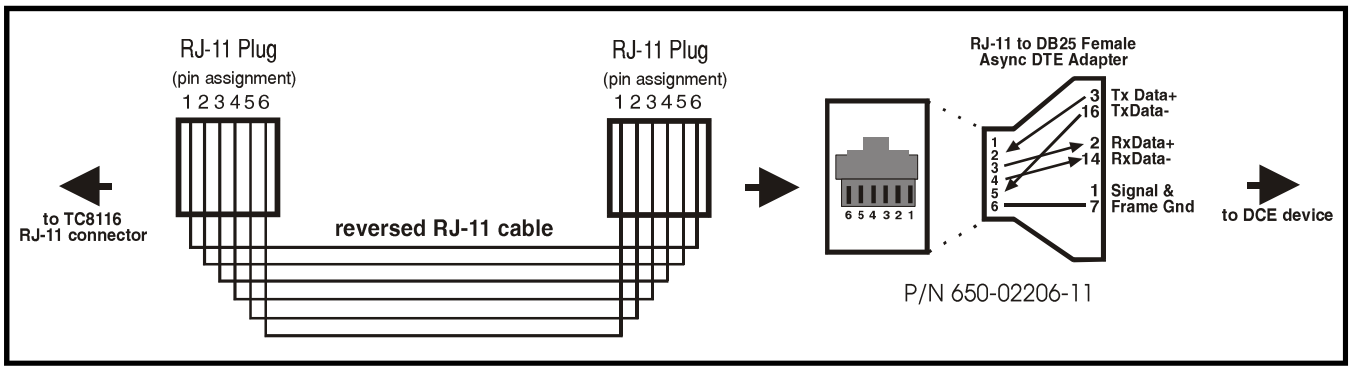


Figure 16. RJ-11 (ASYNC DTE) RS-422/RS-485 Pin Assignments & Connection

Transmission Distances (typical)

The TC8116 will work with all popular sizes and types of fiber. Transmission distances up to 3km* are typical over Multimode fiber at 850nm and 4km* at 1310nm. Distances to 35km* are typical over Single Mode fiber at 1310nm. Transmission distances may vary due to the fiber optic cable's characteristics.

Launch Power & Sensitivity

Transmitter:	LED/ELED; typical Launch Power -	-17dBm* (850nm/1310nm MM, @62.5/125μm)
	LASER;	-8.0dBm* (1310nm Single Mode, @9/125μm)
Receiver:	PIN Diode; typical Sensitivity -	-34dBm* (850nm/1310nm MM, @62.5/125μm)
	LASER;	-36dBm* (1310nm Single Mode, @9/125μm)

**Launch power, sensitivity and distance are listed for reference only. These numbers may vary.*

Fiber Optic Redundancy (optional)

When this option is purchased, the unit is equipped with two pairs of fiber optic Transmitters & Receivers, designated as "TxA," "RxA," "TxB" and "RxB." Both "TxA" and "TxB" transmit the optical signal at the same time. The receiving unit decides whether "RxA" or "RxB" is active. The default receiver is "RxA" unless optic link A fails (either a cable breakage or optic transmitter/receiver fails), in which case the backup link is enabled automatically.

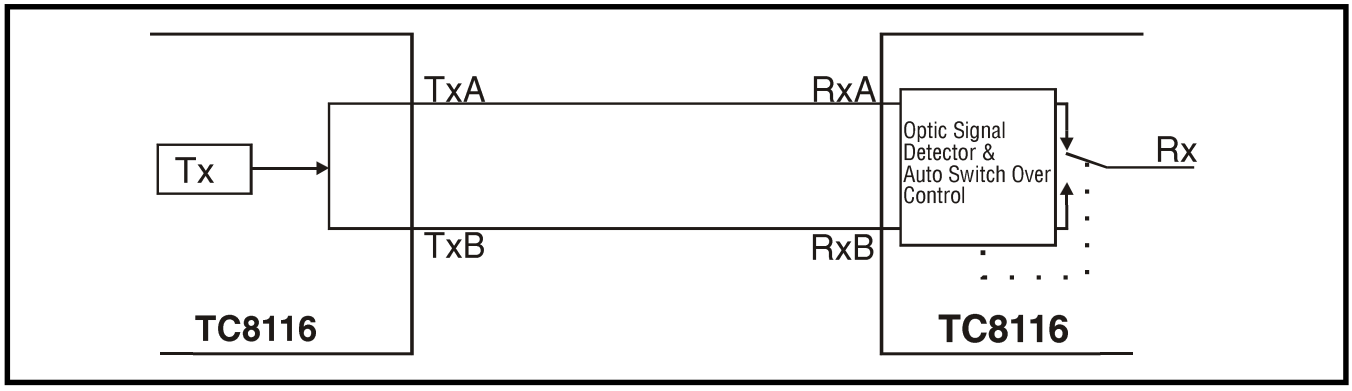


Figure 17. Dual Optics Logic Diagram

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 TC8116 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 or heavy duty power supplies. As with any electronic equipment, keep the unit from excessive moisture, heat, vibration and freezing temperatures.

Dry Contact Alarm Relay

A round jack connector on the rear panel of the A board (labeled "ALM RLY") provides for the Dry Contact Relay Alarm. Normally the dry contact relay is in the OPEN position. When there is an alarm condition, such as the loss of fiber optic signal or loss of power, the dry contact relay will be switched to CLOSED position.

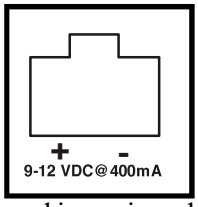
Note: If SW4 (DISALM) on the front panel is in the down position, Alarm function will be deactivated. The on-board audio buzzer will not sound and the dry contact relay will not close under Alarm condition, such as loss of fiber optic signal.

System Configuration

The TC8116 has been pre-tested and switches have been set per factory specifications. The channels can be field configured (in groups of four) for RS-232, RS-422, RS-485, TTL, Dry Contact Relay, Analog or Intercom interfaces.

Power Supply

Each TC8116 card is powered by an external DC power adapter rated 9 to 12 VDC @400mA. There are two terminal block connectors labeled "PWR A" and "PWR B" only one is required to power up the unit. If your system has ten TC8116 cards, the power supply requirement is 10 x 400mA = 4.0A. Either a power adapter or TC Communications' power card can be utilized to supply power to the units.



The power can be plugged into any of the power jacks at the back panel. Since each TC8116 card is equipped with a power redundancy capability, the power LEDs on the front panel will light according to which power jack (A or B) is connected. Both LEDs will light when power redundancy is utilized.

System Start Up

Apply the power by plugging the power plug into a power jack. The power source can be from a power adapter or from a power card (installed either on the left side or right side of the rack). After power is applied (and all DIP switches are set properly), all LEDs (except PWR & Vcc LEDs) will flash momentarily and the following LED status should be observed from the front panel:

1. The Power "A" and/or "B" LED should be lit. The "Vcc" LED should also be lit. If the unit is equipped with dual optional optics (A & B boards), the "RxB" LED should be flashing on the A board.

2. The "ALM" LED should be lit to indicate a "lost optic" condition. It will reset when the unit receives a valid optic signal at "RxA" and "RxB" on optional dual optic models.

3. At the rear panel, apply the electrical signals by plugging in the RJ-11 connector plugs one at a time. Verify the corresponding "IN" LEDs for each particular channel as the connections are made. Each "IN" LED should light to indicate a valid electrical signal connection. If the "IN" LED does not light on a particular channel, it usually indicates incorrect connections at the RJ-11 input port (double-check your connections and verify them with the connection diagrams in the Electrical Signal Interface section). If all the "IN" LEDs are lit prior to the RJ-11 connections being made, flip SW5 to the On position.

Chapter 3 - Troubleshooting

General

Alarm conditions occur whenever an optical problem or "fault" condition is detected by the TC8116. Under normal operation, all LEDs should be lit, with the exception of the "ALM," "USE RxB" and inactive channel LEDs.

All LEDs are Off

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

Alarm LED

The "ALM" LED will light when an optic fault condition exists (such as a cable breakage or a poor optic connection).

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 connectors are frequently the source of various problems. Check out the 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 total loss when installed and suddenly tests out as having a loss of 10dB probably has a connector or link 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 determine actual link loss.*

Chapter 4 - Bench Tests

General

It is highly recommended to conduct bench tests before actual installation. Bench testing allows the user to become familiar with all the functions and features of the TC8116 in a controlled environment. Knowledge of these functions and features will ease installation and troubleshooting efforts later on.

Signal Generator Test

After System Start Up, you should conduct the following test to verify that the unit was not damaged during transportation:

1. Use a short optic jumper cable to form a loop from optic "TxA" to "RxA." Once a valid optic signal is received, the "SYNC," and "RxA" LEDs should light solidly and the Alarm LED should turn off.
2. Slide SW3 (SIG GEN) to the On (Right or Down) position to turn on each board's Signal Generator. The channel "IN" and "OUT" LEDs should light in sequence on all channels. *Note: the Signal Generator function does not apply to Dry Contact Relay interfaces.*
3. Disconnect the optic cable from "RxA." The corresponding channel "OUT" LEDs should be Off while the "IN" LEDs continue cycling through.
4. You may connect the optic jumper cable to a second TC8116's optic "RxA" and observe the channel "OUT" LEDs on the second unit lighting in the same sequence as the first unit's "IN" LEDs.
5. Upon completion of this test, return SW3 (SIG GEN) to the Off (Up or Right) position.

Local Loopback Test

With SW2 (LOCLB) in the On (Right or Down) position and a valid electrical signal is present at the RJ-11, the incoming signal on pin 5 (or pins 2 & 5 for balanced signals) will be looped back to pin 4 (or pins 3 & 4 for balanced signals), and the "IN," and "OUT" LEDs will light solidly and the "LOCLB" LED will flash.

The loopback is formed inside the TC8116, after the input signal is converted to the TTL level. The purpose of this test is to verify the interface's input and output connections, signal input receiver and signal output driver.

Remote Loopback Test

Connect the fiber optic cables from the local TC8116 to the remote TC8116 unit as shown on the diagram below. Apply a valid electrical signal at any of the RJ-11 connectors on the rear of the local unit. The "IN" LED on the local unit should be lit and the "OUT" LED on the remote unit should be lit on the corresponding channel connected to.

Enable SW1 (RMTLB) to the "On" (Right or Down) position on the remote unit, the optic signal received at "RxA" or "RxB" will be looped back to the transmitter ("TxA" or "TxB"). Both "IN" and "OUT" LEDs will be solidly lit on both the local and remote units on the corresponding channel connected to. The "RMTLB" LED on the remote unit will be flashing. This test will verify the optic transmitters, receivers and the optical link between units.

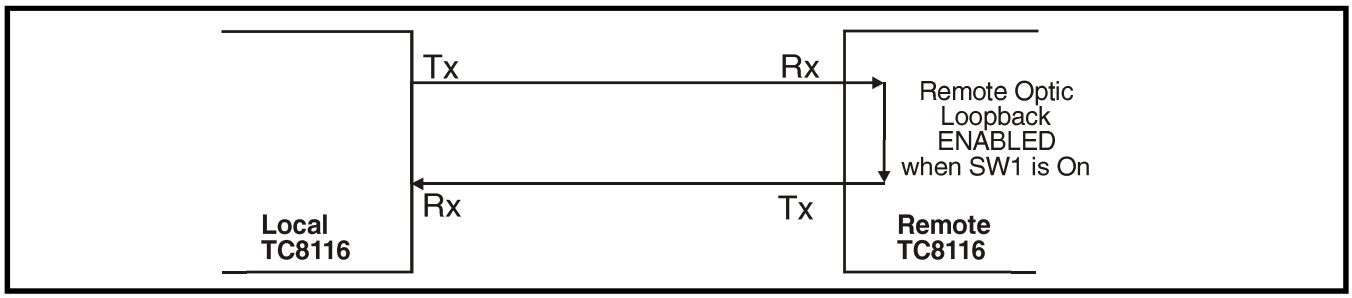


Figure 18. Remote Loopback Logic Diagram

Chapter 5 - Specifications

Data Rates

Async (per channel) ..... DC up to 38.4 Kbps**

Channel Capacity

TC8116-0A ..... 8 Async Channels
TC8116-1A ..... 16 Async Channels
TC8116-0S ..... 8 Sync Channels
TC8116-1S ..... 16 Sync Channels

Optical

Transmitter ..... LED/ELED/LASER
Receiver ..... PIN Diode
Wavelength ..... 850nm/1310nm Multimode
..... 1310nm Single Mode
Fiber Optic Connectors ..... ST* (FC optional)
Loss Budget
..... 15dB Multimode 850nm/1310nm @62.5/125μm
..... 20dB Single Mode 1310nm @9/125μm

Electrical

Connector RJ-11
Interface ..... RS-232, RS-422, RS-485, TTL, Dry Contact Relay, Analog or Intercom
TTL
Input Voltage Maximun Rating ..... -0.5 to 7V
Recommended TTL Input Voltage .....
Vin High ..... 2.0V to 5V
Vin Low ..... 0V to 0.8V

System

Bit Error Rate ..... 1 in 10^9 or better
Visual Indicators (16 Channel units) ..... PWR A, PWR B, Vcc, ALM, SYNC,
..... RxA, RxB, USE RxA, USE RxB, IN (1 each channel),
..... OUT (1 each channel), TxBCLK, TxFCLK, RMTLB, LOCLB, RxOPT, and 8x2.
Diagnostic Functions ..... Local Loopback, Remote Loopback, Signal Generator,
..... Disable Alarm, Inverse Polarity.

Power Source (each card)

Standard ..... 12VDC @400ma
Optional ..... 24VDC @200ma
Optional ..... 48VDC @100ma
Optional ..... 115 or 230VAC with external power cube

Temperature**

Operating ..... -10°C to 50°C
Storage ..... -40°C to 90°C
Humidity ..... 95% non-condensing

Physical Characteristics (each Rack Mountable Card)

Height ..... (17.7cm) 7.00"
Width ..... (3.2cm) 1.25"
Depth ..... (23.0cm) 9.00"
Weight ..... (280gm) 8 oz

**ST is a trademark of AT&T*
***Contact factory for higher data rate & temperature requirements*

Appendix A - 19" Rack & Power Card

Features

- ❒ **4 U height (7")**
- ❒ **Dual Power Capability (Automatic Switchover in the Event of Failure)**
- ❒ **Universal Switching Power Supply Accepts 90V to 264V AC and 47 to 63 Hz AC**
- ❒ **Optional -48VDC Power Supply Available**
- ❒ **Overload & Short Circuit Protection**

Description

The TCRM191 and TCRM192 Universal Rack Mount Card Cages hold up to 10 single multiplexer or modem type cards, or up to 5 double-mux or double-modem type cards. In general, the Model TCRM191 is used for multiplexers and the Model TCRM192 for modems.

Both can operate with one power supply or dual load-sharing power supplies. The AC power supply automatically adjusts for 90V to 264V AC input and 47 to 63 Hz operation. The DC power supply accepts -48VDC input. Both AC and DC power supplies can be mixed in the same unit.

The dual power supplies feature automatic switchover in the event of a power failure. The Power switch and its LED are located on the front panel.

Both rack assemblies are 19" wide by 7" high. The TCRM191 is 9" deep, while the TCRM192 is 5.25" deep.

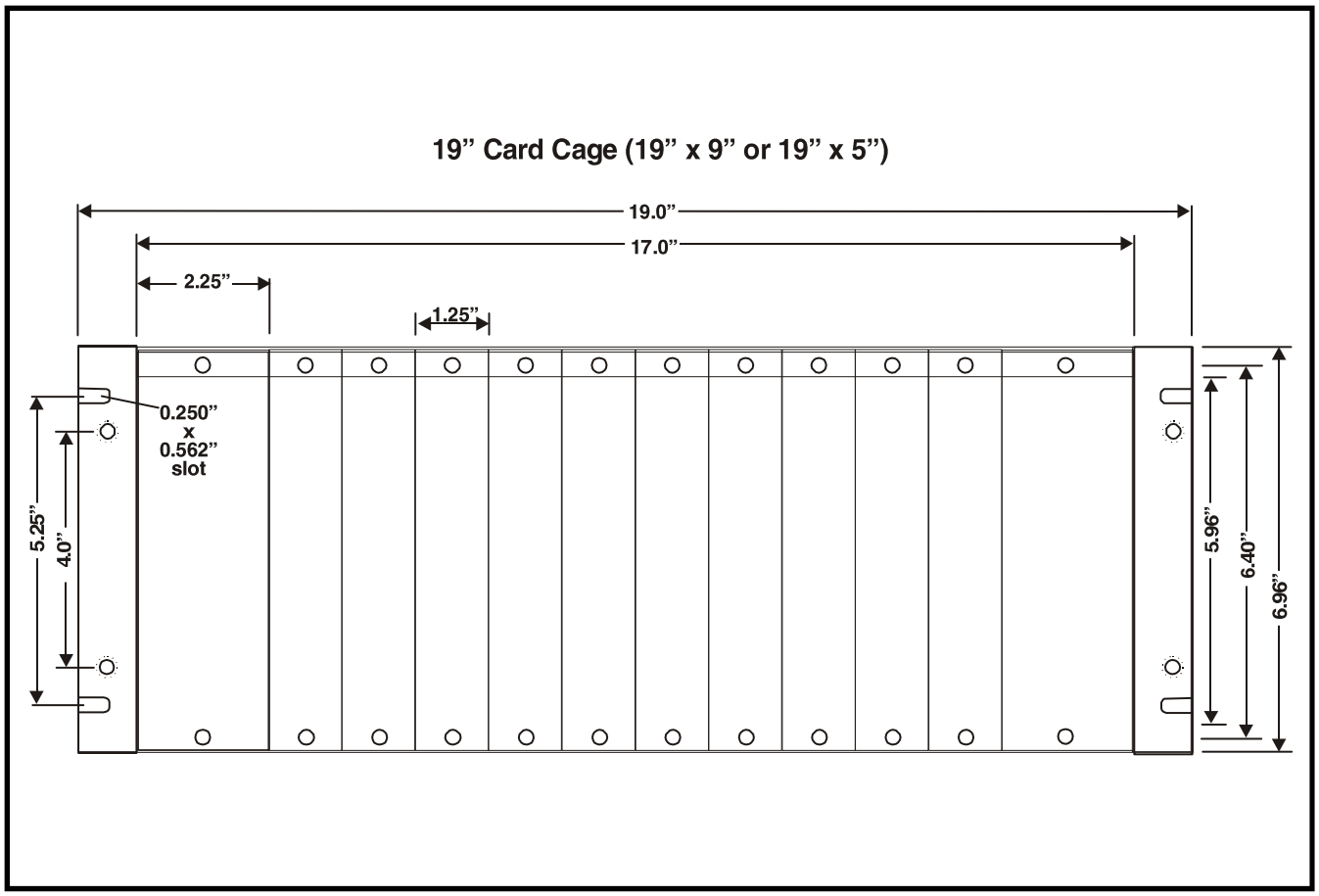


Figure 19. TCRM191/192 Rack Mount Card Cage

Appendix B

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

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.)

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.

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.

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.