INSTALLATION AND OPERATING MANUAL

FOR

SERIAL MULTIPLEX INTERFACE

MODEL 2022	Part No. 710-0018-00
MODEL 2022E	Part No. 800-0070-00

Version 4.04 (year/month)

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SECTION 1
GENERAL INFORMATION

1.1 INTRODUCTION

This manual provides information pertaining to the installation and operation of the Model 2022 Interface (RFID, Inc. Part No. 710-0018-00), or Model 2022E (the E signifying enclosure) (RFID, Inc. Part No. 800-0070-00).

1.2 DESCRIPTION

The Interface Model 2022 is termed Multiplex because it can manage up to 16 addressable Readers and Antennas using time division multiplexing. The Interface Model 2002 provides a full-duplex, asynchronous bit serial data stream which will interface to various equipment compatible with RS-232-C,RS-422-A, or RS-423-A specifications. The Interface is configured as Data Terminal Equipment (DTE).

The 2022 detects, filters and amplifies the data signals relayed by any of the compatible Readers (Models 1845 and 1885) and converts that data into a serial string. Basically, the Interface provides RF to digital translation of the signal produced by RFID, Inc. RF Electronic Labels, which are referred to as "Tags", when placed in the proximity of a Reader/Antenna. Advanced error detection algorithms provide error-free operation. All messages are transmitted in printable ASCII characters in transmit-on-receipt or polled mode.

The Interface provides on its ENABLE outputs, pulses that control the operation of Addressable Readers. In normal operation the Interface produces a pulse to disable all connected Readers, then follows that with pulses that enable each Reader one at a time. During the brief period that each Reader is enabled, the SIGNAL inputs are monitored for the presence of a Tag, and if detected, that Tag's contents are reported along with a hexadecimal channel number identifying the Reader at which the Tag was detected.

Via the serial connection, over which Tags are reported, the Interface can also be commanded to buffer Tags, report multiple Tag readings, repeat the last message, test itself, reset, or delete specified Readers from its polling loop.

The Eurocard format paired with the single supply voltage requirement simplify its integration into existing installations. Connection to the Reader is made using low-cost shielded twisted pair cables and angle entry terminals simplify installation.

1.3 SPECIFICATIONS

Protocol:	Full-duplex, RS232/423 or RS422 Selectable stop bits, parity sense, and word length
Serial Data Rate:	Selectable baud rate, 110, 300, 600, 1200, 2400, 4800, 9600, 19200
Control Signals:	DSR, CTS, DTR
Processing Speed:	Up to 20 Readings/second
Data Storage:	2 Readings
Error Rate:	Less than 1 in 10 to the 14th readings
Connectors	
Serial:	DB-25S
Power:	64-pin DIN 41612 Type C
Readers:	5 position screw type terminal strip
Multiplex Control:	2-wire, Multi-drop scheme, 48mA, max.
Input:	75 Ohms, Balanced, Multi-drop
Cabling Distance to Readers:	Up to 5000 feet, total (with shielded twisted pair cable)
Power Requirements:	+5 Volts DC, +/- 5% @ 350 mA. (max.) 250 mA. (typ.)
Temperature Range	
Operating:	-40 to +70 degrees C
Non-operating:	-55 to +85 degrees C
Dimensions:	
Model 2022:	7.0" x 3.9" x 6.6"
Model 2022E:	9.0" x 5.1" x 1.7"
Weight	
Model 2022:	5.5 oz.
Model 2022E:	1.24 lbs (.56kg)

SECTION 2
INSTALLATION

2.1 INTRODUCTION

This section contains information for unpacking, installing, and configuring the Interface, including power, signal, and enable wiring, and rating power supplies. Installation also includes matching and connecting the Interface to the Host Computer or Terminal.

2.2 UNPACKING AND INSPECTION

If the shipping carton is damaged or shows evidence of abusive handling, inspect the Interface for visible damage including dents, scratches, etc. If the unit appears damaged, contact the carrier and RFID, Inc. Sales or Customer Service Departments immediately. Keep the shipping and packaging material for the carrier's inspection. RFID, Inc. will arrange for repair or replacement of the damaged unit without waiting for the claim settlement with the carrier.

2.3 PREPARING FOR INSTALLATION

The power is provided through the Eurocard connector 64 pin DIN and signal connections are made via a terminal strip on the printed circuit board. If the RFID, Inc. enclosure assembly is not provided for the Eurocard, you must provide a Eurocard DIN connection with +5v on pins a1,c1, and ground on pins a32, c32. To access the inside of the Model 2022E assembly, remove the end plates and remove the printed circuit board assembly. The end plates may be removed by first removing the four corner hex nuts on each end plate which secure it to the assembly. Refer to the Figure 2-1.

Following installation of all Reader wiring, the end plates should be reinstalled using the same screws. The cable gland should be tightened to secure and seal the wiring.

2.4 POWER REQUIREMENTS

The Interface must be powered from a regulated power source (linear supplies are acceptable, switching supplies are out of the question) having the following characteristics:

Voltage DC	Voltage Range:	4.75 to 5.25 volts
	Ripple:	100 mV p-p (max.)
Current	Operating:	350 mA. (max.)
		100 mA. (typ.)

RFID, Inc. can provide a power supply suitable for use with the Model 2022. The Interface should be operated from a grounded supply that has the same ground reference as the host computer. The ground reference used for the Readers may be of a different origin.

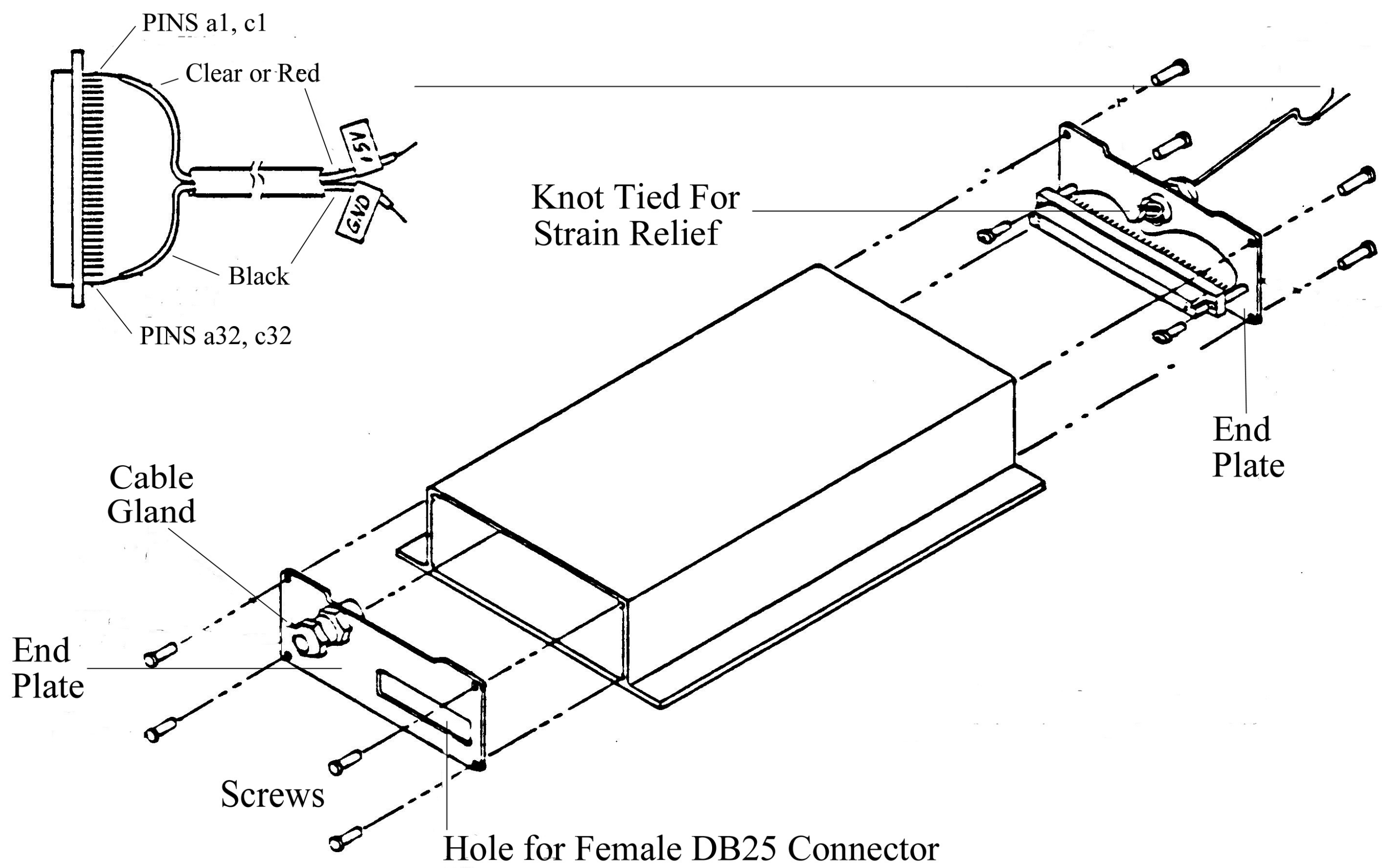

PINS a1, c1
Clear or Red
15V
GND
Black
PINS a32, c32
Knot Tied For Strain Relief
End Plate
Cable Gland
End Plate
Screws
Hole for Female DB25 Connector

Figure 2-1

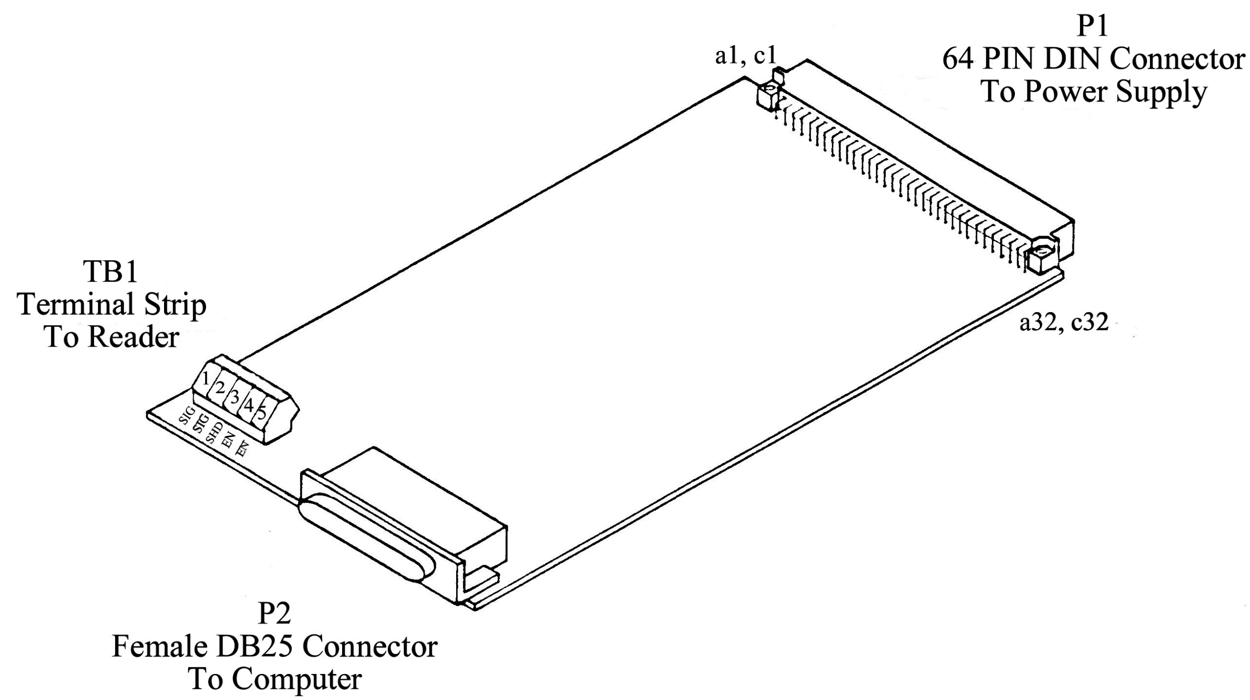

P1
64 PIN DIN Connector
To Power Supply
a1, c1
a32, c32
TB1
Terminal Strip
To Reader
1
2
3
4
5
SIG
SIG
SHD
EN
EN
P2
Female DB25 Connector
To Computer

Figure 2-2

2.5 POWER CONNECTIONS

On the Model 2022E, power wiring is already threaded through the cable gland and connected to the solder tail DIN connector (P1) on the circuit card. There should be a knot in the wire to provide strain relief. Wires should be connected in accordance with the following:

TABLE 2-1 POWER CONNECTIONS

DIN Connector (P1) PIN NUMBER	CONNECTION FROM DC SOURCE
a1,c1	+5v
a32,c32	DC Return (GND)

WARNING
The power source should be turned off while making connections to the reader. It is recommended that the power source remain off anytime the circuit board is removed from its enclosure assembly.

Power connection to the Interface should be made with the power source turned off. There is no onboard over current protection so an external fuse is recommended to protect the power supply if it has no over current protection of its own.

If the Interface is to be used without an enclosure, these mating DIN connectors are recommended for connection of the power wires:

Panduit	100-964-454
Elco	208457096008026
Weidmuller	914605

If the Interface is to be housed in a backplane, make sure that pins a,c2 - a,c31 are left unconnected. These pins are connections to the processor's data bus and can affect the Interface's operation if improperly connected.

A note about power cable length: Long power cables will produce voltage drops resulting in a lower voltage at the Interface end than at the power supply end. There is no inherent limit to the length of wire from the supply to the Interface as long as the high and low voltage specifications are maintained at the Interface.

2.6 READER WIRING

This section describes the signal and enable wiring that connects the Interface to the Readers. The two SIGNAL wires provide the path for RF data from the Readers into the Interface. The two ENABLE wires provide multiplex control from the Interface to the Readers. Shielded, #14 to #28 AWG, insulated, stranded wire is recommended and all wires should be stripped approximately 3/8 inch and tinned. The following cables are recommended:

TABLE 2-2 RECOMMENDED CABLES

APPLICATION	CABLE DESCRIPTION	RECOMMENDED TYPE
Signal Only	Cable, Paired, 2 Conductor	RFID 214-2202-00 or
	#22 AWG with foil shield	Columbia C2514
Enable Only	Polyethylene & PVC, 60 Deg C	Manhattan M13226
		Belden 8761
Signal	Cable, Paired, 4 Conductor	RFID 214-2204-00
and	#22 AWG (1 Pr.) with foil shield	Alpha 2464
Enable	#22 AWG (1 Pr.) unshielded	Manhattan M4451
	Polypropylene & PVC, 60Deg C	Belden 8724
Signal and	Cable, Paired, 6 Conductor	RFID 214-2206-00
Enable and	#24 AWG (2 Pr.) with foil shield	Manhattan M14477
Power	22 AWG (1 Pr.) unshielded	Belden 8786
	PVC, 80 Deg C	

Whatever cable is selected should fit within the range allowed by the cable gland providing wire access to the reader. The cable gland will accommodate diameters of .090 to .265 inches.

A note about "PLENUM" cabling, plenum cable eliminates the need for using conduit when installing cables in air plenums. In typical modern buildings, a plenum exists between the drop ceilings and the floors that support them. Because these air ducts often run across an entire story they can be a convenient place to run cable, but they can also be an invitation to disaster if fire breaks out. Fire and smoke can spread rapidly throughout the air duct system if the fire is able to feed on combustible materials. The cables designated Plenum are approved by the NEC and UL because of their flame-resistant and low smoke emission properties. While Plenum cable costs more than conventional cable, the overall installed cost is generally less because it eliminates the need for conduit installation.

PLENUM	
Cable, Paired, 2 Conductor	Belden 89182
#22 AWG with foil shield	
NEC 725, Class 2 classified	

2.7 READER CONNECTIONS

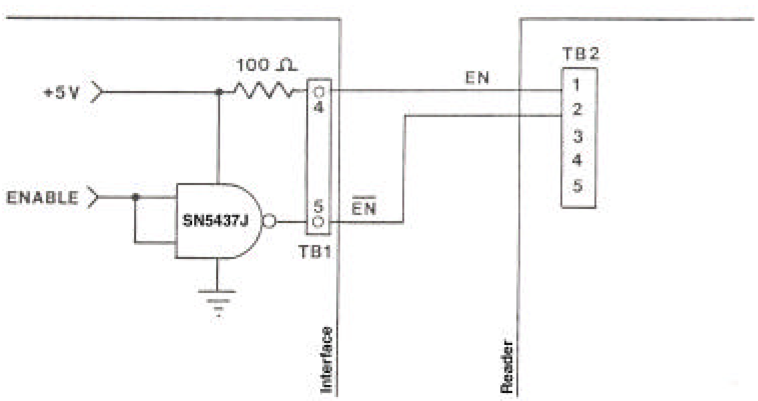
On the Model 2022E, wiring should be fed through the cable gland and connected to the angle entry terminal strip (TB1) on the circuit card. Wiring should be connected in accordance with the following:

TABLE 2-3 READER CONNECTIONS

TERMINAL STRIP (TB1)	NOMENCLATURE	CONNECTION
1	SIG	SIG on Reader
2	$\overline{SIG}$	$\overline{SIG}$ on Reader
3	SHD	NO CONNECTION IF CONNECTED ON READER
4	EN	EN on Reader
5	$\overline{EN}$	$\overline{EN}$ on Reader

2.8 ABOUT ENABLE AND REMOTE ENABLE

The Reader operation may be controlled (enabled, disabled) from the Interface via the enable outputs (EN, $\overline{EN}$) to the Reader. This is termed remote enable. Alternatively, a shorting jumper or shunt may be placed across J1 on the circuit board of the Reader assembly. The shunt overrides the remote enable control and continuously enables the Reader. This feature is maintained primarily for us, the manufacturer as a testing and quality control tool. It is not recommended for use outside of testing the Reader. The Reader is not normally supplied with the shorting shunt installed on J1. Refer to your Reader manual for specific instructions. The typical circuit connection for the remote enable feature is shown below.



2.9 ABOUT SHIELDING

Shielding is recommended for both signal and enable wiring especially if long lengths of wire are used, or when operating in an environment of high electromagnetic noise. Each wire's shield should be connected at only 1 point, connecting both ends of a shield will produce a closed loop in which noise has no way to exit. A daisy chain connecting multiple Readers counts as a single wire, and the shields should be connected together, but not to the Reader, at each drop along its run. Since shield connections are recommended at the source of the associated signal, SIGNAL shields are connected to Readers and ENABLE shields are connected to the Interface. If the SIGNAL wires are combined in the same cable with the ENABLE wires their shields are common and connected to one Reader. There is an excellent wiring drawing contained in both the Model 1845 and 1885 manuals.

2.10 MATING THE INTERFACE TO A COMPUTER

Communication characteristics, speed, parity, and number of bits per character, must be matched between the Interface and the connected host. If the Interface is talking at 2400 baud (bits per second) and the host at 4800, they'll never understand each other. Most hosts can be configured to a number of different speeds and formats. Some, however, cannot. That's why the Interface can be set to operate from 110 to 19,200 baud. If your host is stubborn, match the Interface to the host's settings. If your host is flexible 19,200 baud is recommended with 7 bits per word and 1 stop bit so the Interface can spend less time communicating and more time looking for Tags. Parity, either even or odd, is recommended for reliability and RS-422 is more reliable than RS-232 but is generally less available for a variety of hosts.

PCB address P3 and P4 consist of pins and jumpers. Default communication characteristics are set by installing or removing the jumpers. Thus shorting together or leaving the pin pairs open. The "removed" jumpers may be left on a single pin so they won't become misplaced should someone want to change the configuration at a later date. The position of the P3 jumpers is read at reset so configuration changes are not registered until a subsequent power up or software reset.

2.10.1 SETTING THE SERIAL TYPE AND APPLICABLE DOCUMENTS

Pins at PCB address P4 are used to select between RS-232 or RS-422 voltage levels and consist of three pins and a jumper used to short two of them together. With the Interface oriented as shown in Figure 2-3, place the jumper on the center and right-most pins to select RS-232 operation. If the jumper is placed on the center and left-most pins RS-422 operation is selected. The P4 jumper, actually changes voltage references to the communication receivers and drivers and its effects are registered immediately at connector P2, which should be left unconnected while changing P4.. Following are documents that generally explain serial communications

EIA Standard, RS-232-C August, 1969
EIA Standard, RS-422-A December, 1978
EIA Standard, RS-423-A December, 1978
RFID, Inc. Interface Specification 710-0004-021

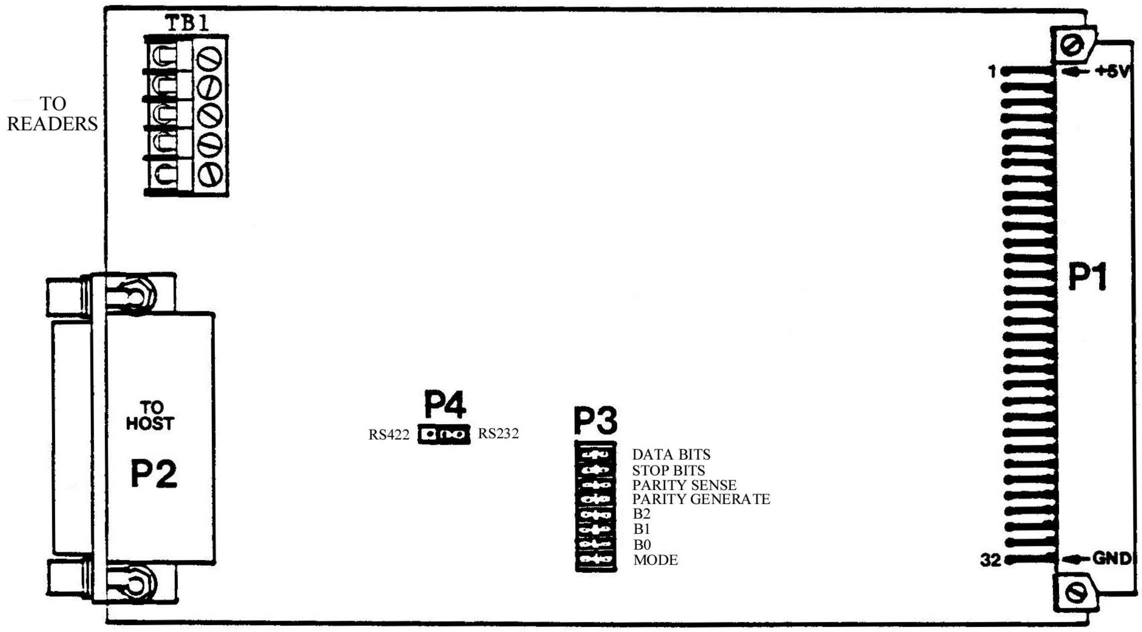


FIGURE 2-3 JUMPER SELECTIONS

2.10.2 ASCII FORMAT

The word format: data bits per character, number of stop bits, and parity is set with the top 4 jumpers on P3. These positions are silk screened with mnemonics: 7B for 7 bits, 2S for 2 Stop bits, EV for Even parity, and ON for parity On. The table below lists the jumpers in the positions that they appear on the board and explains their functions further.

		JUMPER	
LABEL	PARAMETER	ON	OFF
7B	Data Bits per Character	7	8
2S	Stop Bits per Character**	2	1
EV	Parity Sense (if ON)*	Even	Odd
ON	Parity Generate and Receive	On	Off

* If Parity is Off, no parity is generated or checked regardless of the position of the Parity Sense jumper.

** If Parity is ON and 8 bits per character is selected, one stop bit is transmitted regardless of the Stop Bit jumper.

2.10.3 DATA TRANSFER RATES, BAUD

The Interface's baud rate is set with the bottom 3 jumpers of P3. Baud transfer selections range from 110-19200. The Interface requires up to 800 microseconds to process received characters;

accordingly, it may be necessary to provide a delay between characters transmitted to the Interface at the highest baud rates. All possible combinations of the 3 jumpers, on or off, result in the following 8 possible baud rates:

Baud Rate	P3 Jumpers:	B2	B1	B0
110		OFF	OFF	OFF
300		OFF	OFF	ON
600		OFF	ON	OFF
1200		OFF	ON	ON
2400		ON	OFF	OFF
4800		ON	OFF	ON
9600		ON	ON	OFF
19200		ON	ON	ON

2.10.4 SERIAL CABLING

The Model 2022 Interface connects to the host via 25-pin, female "D" connector - P2. Therefore, a cable with a 25-pin, male "D" connector on one end and the appropriate connector required for the host on the other end must be built or purchased.

Determine which type of equipment you have for your host. Any <u>one</u> of these combinations will suffice.

* If you have Data Communications Equipment (DCE) with a female DB25 connector, use a DB25 male/male cable assembly. RFID can provide this component, P/N 730-0001-xx, with the last 2 digits indicating your desired cable length in feet.

* If you have DCE with a male DB25 connector, use the above indicated cable assembly and a female/female connector adapter that is a gender changer.

* If you have Data Terminal Equipment (DTE) with a male DB25 connector, use the cable assembly and a connector adapter modem eliminator (RFID P/N 730-0003-00). The modem eliminator switches the activity on pins 2 & 3, so that they do not transmit and receive on the same lines.

* If you have DTE with a female DB25 connector, you must again use the cable assembly and the connector adapter modem eliminator. You must also utilize a female/female connector adapter to change the gender of the DB25 connector.

2.10.5 SERIAL CONNECTION

The Interface is configured as Data Terminal Equipment (DTE) meaning that it transmits its data on pin 2 and receives data on pin 3. Since most terminals and IBM-PC compatible interfaces are also configured as DTE, the interface cable will probably have to connect the Interface's pin 2 to the host's pin 3 and the Interface's pin 3 to the host's pin 2. There exist simple converters called modem eliminators, which accomplish this, discussed in the section above. Since RS-232 and RS-422 pin designations are not standardized, check your host's operating manual for verification. The important thing is to connect the Interface's Transmit Data (TD) signal (pin 2) to the host's Receive data (RD) signal, the Interface's Receive Data (RD) signal (pin 3) to the host's Transmit Data (TD) signal, and the Interface's Ground (pin 7) to the host's Ground. The table below lists the signals present on the Interface's DB-25 connector P2 and their usage for each of the possible RS interface standards.

PIN#	SIGNAL NAME	DIRECTION	RS232	RS423	RS422
2	TD - Transmitted Data	From Interface	R	R	R
14	TD* - Inverted TD	From Interface	U	U	R
3	RD - Received Data	To Interface	R	R	R
16	RD* - Inverted RD	To Interface	U	U	R
7	GND - Signal Ground	-	R	R	R
6	DSR - Data Set Ready	To Interface	O	O	O
11	DSR* - Inverted DSR	To Interface	U	U	O
20	DTR - Data Terminal Ready	From Interface	H	H	H
18	DTR* - Inverted DTR	From Interface	U	U	H
5	CTS - Clear To Send	To Interface	O	O	O
13	CTS* - Inverted CTS	To Interface	U	U	O
**	RTS - Request To Send	From Interface	H	H	H
**	RTS* - Inverted RTS	From Interface	U	U	H
25	+5V - Power-OOO				

Usage Symbols:
R - Required for this configuration
U - Unused in this configuration
O - Optional, Interface doesn't care*, Host may
H - Host dependent, see Host's requirements

* When the DSR and CTS inputs are left unconnected, they are normally read as "true" levels. However, in high EMI situations, it is recommended that unused DSR or CTS inputs be connected to the +5V power and unused DSR* or CTS* inputs be connected to GROUND.

** Due to Line Driver limitations, the Request To Send signal is not present at connector P2. It is implemented by the Interface's ACIA, and asserted true before each transmission is initiated. If desired, Data Terminal Ready (which is true whenever the Interface is on) can be replaced with Request to Send by cutting the trace from U2 pin 11 to U3 pin 7 and adding a jumper from U2 pin 8 to U3 pin 7.

The Interface does not require the complete RS-232 protocol to operate but some hosts do. If you would like to bypass this regimen on the host the easiest thing to do is connect the Host's DSR to its DTR and its RTS to its CTS. This is accomplished with 2 jumpers on the host's "D" connector. Check your host's operating manual for its protocol requirements and the corresponding pin numbers.

2.11 DEFAULT OPERATING MODE

The remaining jumper on P3, "M2", directs the Interface to select between Polled or Non-polled operation. Mode 2 or polled operation is selected if this jumper is on at reset and causes the Interface to buffer Tags until a transfer command is received from the host. Mode 1, selected if the jumper is removed, causes the Interface to transmit its detected Tag data once immediately upon detection. There is a Mode 3 as well that can only be selected through a software command. The default mode can also be changed by the host via a Mode Command, discussed in the third section of this manual.

2.12 AUXILIARY PORT FOR LCD

The Model 2002 Interface contains an 8-bit parallel auxiliary port that may be utilized to drive an LCD Display. If not used, the connector pins for this port should be left open so that operation of the Interface is not affected by external conditions. The pins used for the auxiliary port are c22 through c31 on connector P1.

2.13 INSTALLATION COMPLETE - POWER UP MESSAGE

Installation should now be complete. You can see how you did by preparing the host for communication and applying power to the Interface. Whenever the Interface is powered up or reset, it issues a power up message. The issuance of this message signifies to you at least one-way communication, the transmission function, is working properly and also advises the host that a reset has occurred so it can reset any non-default operating characteristics, assuming you include this in your software. The power up message is preceded by a Line Feed (<LF>) and followed by a Carriage Return (<CR>) like all messages out of the Interface. For the Model 2022, the power up message consists of an 18 character string:

ELECTRONIC-LABEL**

For the Model 2022/8 (covered later), the power up message consists of a 10 character string:

RFID-LABEL

To test communication from the host to the Interface, issue a Carriage Return. The response you get should be that of a question mark.

SECTION 3
OPERATION

3.1 INTRODUCTION

This section explains operating information for the Interface. It describes its theory of operation, timing, commands, operating modes, and responses.

3.2 THEORY OF OPERATION

The Interface has 3 main functions: 1) monitor the SIGNAL inputs from the Readers for the presence of Electronic Tag data, 2) generate pulses on the ENABLE lines to control the Readers so that only one is enabled at any time, and 3) communicate over the serial interface to meet the specific needs of the user.

The Interface controls Reader operations by issuing 3 different types of pulses on the ENABLE lines. The pulses are differentiated by their duration and have the following effect:

		Microseconds		
PULSE		Min	Max	DESCRIPTION
RESET	2.0	3.0		Disables all Readers.
READ		1.0	1.6	Indicates valid Tag Read.
INCREMENT		0.3	0.8	Sets and Increments Reader Addresses

The Interface normally provides +5V DC (nominal) at the ENABLE output and 0 to 0.5V DC at the ENABLE RETURN outputs. Pulses are generated by momentarily raising the ENABLE RETURN output to +5V DC. The Interface performs its multiplexing by first generating a RESET pulse. Upon detection of the RESET pulse, all Readers disable themselves for the duration of the pulse. When the pulse is terminated, Reader #0 is left enabled and the Interface checks its SIGNAL inputs for valid data. If it detects signals at this point it knows that the Tag is at Reader #0. The Interface then generates an INCREMENT pulse that disables Reader #0 and enables Reader #1. The Interface continues enabling Readers and checking for data until all Readers have been checked then starts the loop again.

The Interface can be instructed, via the serial interface, to ignore certain Readers in which case it generates two consecutive increment pulses at the appropriate Reader address, without checking the SIGNAL inputs in between. Normally, the Interface looks at the SIGNAL inputs for a minimum of 14 milliseconds. If it sees a Tag during this time, it will extend the interval until the next INCREMENT pulse, to finish reading the Tag.

If the Interface detects a Tag, it generates a READ pulse. The Readers generate a read indication upon detection of this pulse and it also functions to increment the active Reader just like the INCREMENT pulse.

3.3 TIMING

This section describes the timing characteristics for Tag reading when the Interface is connected to a number of Addressable Readers. There is a tradeoff between the speed a Tag can travel past a Reader's Antenna, and the number of Readers installed on a single Model 2022 Interface. Also impacting the speed quotient is the size of the Antenna and the read window it produces.

We can supply you with a document that equates Antenna sizes and the number of Readers installed on an Interface to the physical Tag speed possible.

There is also a tradeoff between Tag data capacity and Tag processing speed, which of course affects the speed issues discussed above. To increase physical Tag speeds to an even greater level, there exists a Model 2022/8, the slash 8 standing for 8 character Tags instead of the normal 16. While not heavily marketed, since it reads Tags programmed with shorter data strings, the Model 2022/8 can detect, process, and transmit the messages faster.

Section 3.3.1 below discusses the timing characteristics of the Model 2022 at length. Because the two models are so similar, the discussion applies also to the Model 2022/8. Only parameter values change. Section 3.3.2 summarizes the equations and parameters used in the calculations of section 3.3.1, but also includes the parameters for the Model 2022/8.

3.3.1 WORSE CASE TAG REPORT TIMING

This section deals with what's referred to in computer jargon as "worst case" situation. The worst-case situation that is addressed here is if 16 Readers are connected to a Model 2022 Interface and a Tag arrives at each one at the exact same time: how long will it take to report all of them, and what is the fastest the Tags can be moving past the Reader's Antenna and still all be detected. Mode 1 operation is also assumed.

The delay until the 16^{th} Tag is reported is dependent on the baud rate used to transmit the Tag data. Obviously, if the Model 2022 Interface is transmitting at 110 baud it will take much longer to report 16 Tags than at 19,200. Each Tag takes approximately 50 milliseconds, worst case, to detect and process. Add to this the transmission time: 20 characters per Tag (16 data characters, 2 characters for channel ID, BOM Line Feed, and EOM Carriage Return) times 12 bits per character (worst case: 1 Start bit, 8 data bits, 1 parity bit, and 2 Stop bits) makes 240 bits transmitted per Tag. At 110 baud (bits per second) each Tag takes over 2 seconds to transmit, at 19,200 baud each Tag takes only 12.5 milliseconds (.0125 seconds). Adding the 50 millisecond processing time to the transmission time and multiplying it by 16 Readers gives the following worse case delays for the last Tag when 16 hit the Reader simultaneously:

BAUD RATE	SYSTEM DELAY
110	35.71 seconds
300	13.60 seconds
600	7.20 seconds
1200	4.00 seconds

2400	2.40 seconds
4800	1.60 seconds
9600	1.20 seconds
19,200	1.00 seconds

Once the worse case delay times are determined, the maximum speed at which 16 Tags can move past Readers can be calculated by determining the length of the Reader Antennas' read fields and substituting that length and the delay time into the familiar equation R * T = D, rate times time equals distance. For example, if Tags travel past Reader Antennas with read fields of 0.7 foot and the Model 2022 is set to 19200 baud:

Max Rate * 1 sec = 0.7 ft
Max Rate = .7 ft / 1 sec or 0.7 foot per second

A more general worse case delay equation may be written to evaluate systems without as many constraints as the system above. For example, there could be a Model 2022 with 16 Readers but only 2 possible Tags to be read. Although it takes 50 milliseconds plus transmission time to report a Tag, it takes a maximum of 30 milliseconds for the Model 2022 to determine that there is no Tag. The Model 2022 can also be instructed to ignore certain Readers via the Assign Command. This impacts the worse case system delay time because the Model 2022 doesn't spend any time looking at omitted Readers. The equation to calculate system delay time (Td) works out as follows:

Where: Tr = 50 milliseconds it takes to read and process
Tn = 30 milliseconds it takes to check a Reader w/o Tag
Tt = Transmit time for complete Tag, see table below
#P = # of possible simultaneous reads
#S = # of Assigned Readers
Td = #P * (Tr + Tt) + (#S - #P) * Tn

To save you some time, Tt is calculated below for the 8 possible baud rates based and all possible number of bits per character available with the different transmission configurations. When calculating the number of bits per word don't forget to count the Start Bit.

BAUD RATE	9	10	11	12
110	1.636364	1.818182	2.000000	2.181818
300	.600000	.666667	.733333	.800000
600	.300000	.333333	.366667	.400000
1200	.150000	.166667	.183333	.200000
2400	.075000	.083333	.091667	.100000
4800	.037500	.041667	.045833	.050000
9600	.018750	.020803	.022917	.025000
19200	.009375	.010417	.011458	.012500

The equation can be used to prove the results of the worse case delays calculated earlier. A Model 2022 with 16 Readers and 10,000 Tags has #P of 16 since only 16 can be read at once, if the Model

2022 is set to 19,200 baud with 12 bits per character Tt = .0125. Hence:

$$
\begin{aligned}
Td &= 16 * (.050 + .0125) + (16 - 16) * .030 \\
&= 16 * (.0625) + 0 * .030 \\
&= 1.00 + 0 \\
&= 1.00 \text{ second, same as above}
\end{aligned}
$$

If there are only 2 Tags and 16 Readers, #P becomes 2 and the equation works out:

$$
\begin{aligned}
Td &= 2 * (.050 + .0125) + (16 - 2) * .030 \\
&= 2 * (.0625) + 14 * .030 \\
&= .125 + .42 \\
&= .545 \text{ seconds}
\end{aligned}
$$

These Tags could travel at: Rate = 0.7 ft / .545 sec, or 1.28 feet per second.

If eight Readers were eliminated from the Model 2022's polling loop via the Assign Command #S becomes 8 and the equation works out:

$$
\begin{aligned}
Td &= 2 * (.050 + .0125) + (8 - 2) * .030 \\
&= 2 * (.0625) + 6 * .030 \\
&= .125 + .18 \\
&= .305 \text{ seconds}
\end{aligned}
$$

And could travel at Rate = 0.7 ft / .305 sec, 2.29 feet per second.

3.3.2 TIMING SUMMARY

This section summarizes the timing equations and parameters for both Interface models:

Parameter	Definition	Model 2022	Model 2022/8
#P	# of reportable Tags	1-16	1-16
#S	# of Readers addressed	1-16	1-16
Tr	Time to read/process Tag	l50 msec	28 msec
Tn	Time to test Reader w/o Tag	30 msec	20 msec
L	Number of characters per report	20	12
B	Baud rate, bits/sec	110-19200	110-19200
N	Number of bits/character	9-12	9-12

EQUATIONS

$$
\begin{aligned}
Tt &= \text{time to transmit a Tag report} \\
&= (L * N) / B
\end{aligned}
$$

Td = time to detect and report all reportable Tags
= #P * (Tr + Tt) + (#S - #P) * Tn

3.4 DATA PROTOCOL

The data protocol utilizes ASCII characters for all data from the Interface and all control functions from the host computer. Each message includes delimiters at the start and end of message. Delimiters used for messages from the Interface are Line Feed (<LF>) at the start of message and Carriage Return (<CR>) at the end of message. For Commands into the Interface, the start of message delimiter may be either Line Feed (<LF>) or a left hand bracket ([) and the end of message delimiter may be either Carriage Return (<CR>) or a right hand bracket (]).

The protocol allows the Interface to be connected to a variety of computer systems, printers and terminals. Since special ASCII control characters are avoided, software in the host computer can be written in higher level languages without the need for special device driver routines.

3.5 ISSUING COMMANDS TO THE INTERFACE

All commands must be issued in CAPS.

There are eight command types by which the Host Computer can control the operation of the Interface. These commands are:

I	INITIATE SELF TEST
A####	ASSIGN READERS
M#	MODE CONTROL
B####	BUFFER RESET
T	TRANSFER REQUEST
R	REPEAT MESSAGE
K####	SET ACCESS KEY
S	SYSTEM RESET

Each command has its own functions, discussed in the following sections, but they are all entered in the same manner. Each command must be preceded by a Beginning of Message (BOM) delimiter and followed by an End of Message (EOM) delimiter. The BOM delimiter can either be a Line Feed (ASCII 0A hex) or left square bracket: [(ASCII 5B hex). The EOM delimiter can either be a Carriage Return (ASCII 0D hex) or right square bracket:] (ASCII 5D hex). The two types of delimiters can be mixed, i.e. [T<CR> is acceptable. Note that terminals that issue a <CR> followed by a <LF> automatically send the BOM delimiter for the next command. The BOM delimiter is held for an indefinite length of time so that commands can be entered with two keystrokes. The # character in the list of commands represent data required for the associated command.

The Interface does not recognize backspaces or delete keys, but the BOM delimiter clears out any already entered information. Therefore if a mistake is made while entering a command, it isn't necessary to backspace and fix it, simply start it over with a new BOM delimiter.

INITIATE SELF TEST – [I]

Type this: [I]

The Interface performs a comprehensive self test, indicates its Mode 3 status, and displays its firmware version. The internal tests performed are of the ACIA - communication circuitry, RAM - internal memory, ROM - program memory, and the processor's internal timer. The results of each test are transmitted as they are completed with a "1" indicating the successful completion of a test and a "0" indicating failure. If any of these tests fail, contact RFID for corrective action.

Successful self test will read as follows:
"111111111(Vn.nn)" for Modes 1 & 2 and "101111111 (Vn.nn)" for Mode 3, followed by the System Reset, "ELECTRONIC LABEL".

The first nine characters represent in order:

ACIA test
Duplicate Tag test (0 = Mode 3, 1 = Mode 1 or 2)
Not used
RAM test
ROM test
Timer test
Not used
Not used
Firmware release version followed by M(Vn.nn) where n.nn is the release number. A SYSTEM RESET follows this transmission.

Following the transmission of the Self Test message, the processor goes idle to allow the system "WATCHDOG" to generate a hardware reset. This reset should generate a power up message. Failure to receive the power up message should be regarded as a problem that should be corrected before the Interface can be reliably used.

The WATCHDOG is a circuit that must be continually pulsed by the microprocessor's firmware. If the microprocessor gets hung up due to a power surge or processor failure it will automatically reset itself. The idle mode at the end of the Self Test tests this feature.

ASSIGN READERS – [A####]

Type this: [A####] where # equals the hex addresses explained below.

The Assign command can be used to instruct the Interface to eliminate Readers from its polling loop. The format of the command is a capital A followed by 4 hexadecimal digits 0 - F. If used, hex digits A - F must be capital letters. The 4 digits represent a binary bit map of the Readers to be polled with a binary "1" signifying that the corresponding Reader is to be polled, and a "0" signifying that the corresponding

Reader is to be skipped. The first digit following the command "A" corresponds to the highest addressed Readers F thru C and the last digit corresponds to the lowest addressed Readers 3 thru 0. The most significant bit of each digit corresponds to the highest addressed Reader of that group. The default mode of the Interface is to include Readers 0 thru F in its polling loop that is the equivalent of an [AFFFF] assignment.

A simple way to construct the data characters for a desired Reader assignment is to list the desired state of each Reader, left to right, starting with Reader F (15), with a 1 for an enabled Reader and 0 for one disabled. Group the 1's and 0's into groups of 4 then replace the 4 binary bits with the equivalent hexadecimal value from the table below.

0 – 0000	4 – 0100	8 – 1000	C - 1100
1 – 0001	5 – 0101	9 – 1001	D - 1101
2 – 0010	6 – 0110	A – 1010	E - 1110
3 – 0011	7 – 0111	B – 1011	F - 1111

For example, for Readers 0, 1, 2, 3, 4, 5, and B ON, all others OFF, starting with Reader F list the 1's and 0's:

Reader address: F E D C B A 9 8 7 6 5 4 3 2 1 0
Reader status: 0 0 0 0 1 0 0 0 0 0 1 1 1 1 1 1

Arrange the bits into groups of 4: 0000 1000 0011 1111

Substitute the hexadecimal value: 0 8 3 F

Resulting command for this configuration: [A083F]

The most efficient way to configure less than 16 Readers is to have contiguous enabled Readers starting with address 0. The Interface generates the Reset pulse after the last enabled Reader and a contiguous configuration keeps the Interface from generating excess Increment pulses.

A special case of the Assign Command: [A0000] causes the Interface to raise the ENABLE RETURN signal to a high, cease generating Reader control pulses, and quit searching for Tags. Any other Assign command will restart the polling sequence.

If an error is detected in an Assign Command, the error will be reported by an Invalid Command message: "?" and the Reader assignment will remain unchanged.

MODE CONTROL COMMAND - [M#]

Type this: [M#]
This command switches the Interface between its various operating modes.

Mode #1 - [M1] Single Report, Transfer on Receipt
The Interface continually scans for Tag reads via the Reader and transfers the

information immediately to the host system, once.

Mode #2 - [M2] Polled Operation
This mode also continually scans the Reader for Tag reads, but stores the data for subsequent retrieval when requested by the host computer. Due to limited processor memory, only two Tags can be buffered by the Interface, therefore, care must be taken to ensure that the Interface is polled frequently enough that no Tags are missed because of full buffers. To request this stored information use the command the Transfer Request Command.

Mode #3 - [M3] Report Duplicate Tags
This Mode continually scans for Tag reads via the Reader and transfers the information immediately to the host system, repeatedly, as long a Tag is detected in the Reader/Read Head's signal field. The only exit from Mode 3 is via the System Reset command or by cycling power.

The default Mode is set during Reset or Power Up according to jumper M2 at PCB address P3. The default mode may be changed via these commands.

TRANSFER REQUEST COMMAND - [T]

Type this: [T]
The Transfer Request is used in Mode 2 to instruct the Interface to transmit a single Tag's data. If a Tag has been detected since the last Transfer Request, its data will be transmitted along with the Reader identifier in the standard format. If a Tag has not been detected, an Empty Buffer message - "e" will be transmitted. It is recommended that at least 70 milliseconds occur between Transfer Requests to allow the Interface to search for Tags. It is also recommended that consecutive Transfer Requests be issued until receipt of the "e" - Empty Buffer Message. The Interface keeps the last message transmitted in its on-board memory in case a transmission error is detected by the host and it requests a retransmission. Due to limited memory, this Tag retention takes up one Tag buffer. Issuing subsequent Transfer Requests effectively acknowledges the successful reception of the last Tag transmitted and frees up that memory for Tag data.

If received by the Interface while it is in Mode 1 or 3, the Transfer Request will cause a "?" - Invalid Command message to be issued by the Interface.

BUFFER RESET COMMAND - [B####]

Type this: [B####]
The Buffer Reset Command allows the reporting of a previously reported Tag if re-detected. In Modes 1 and 2, Tags are detected multiple times but reported only once per detection at a given Reader. If the Tag is removed from the field for two seconds or more, then re-introduced, it is re-reported without this command. This command allows the same Tag to be re- reported at the designated Reader without being removed for two seconds. The Readers are designated by the four hexadecimal

characters following the "B". If other than four characters 0 - F are received for data, no buffers will be reset. The four data characters correspond to Reader numbers in the same way as the Assign Command, representing a bit map of the 16 Readers with the most significant bit of the first character corresponding to Reader F and the least significant bit of the last data character corresponding to Reader 0. A "1" bit directs the Interface to re-allow reporting of a duplicate Tag at the corresponding Reader. A "0" bit has no effect on the corresponding Reader.

The command [BFFFF] resets all 16 Reader buffers. Since the command [B0000] would have no effect, it has been given the function of clearing the Mode 2 Tag transfer buffer. As discussed under the [T] Transfer Tag command, as each Tag is transmitted it is retained in the Interface's memory in case a transmission error is detected by the host and it requests a retransmission of the same data. The [B0000] command clears this retained data and may be used to acknowledge the successful reception of data by the host.

REPEAT MESSAGE COMMAND - [R]

Type this: [R]

The Interface repeats the previous transmitted message. This command may be used if parity errors, framing errors, etc. are detected by the host.

The Repeat message should be issued as soon as possible to avoid "losing" the last Tag transmitted in Mode 1. If the Tag buffer is refilled by a new Tag before the Repeat command is processed, an "e" - Empty Buffer message will be transmitted.

SET ACCESS KEY COMMAND - [K####]

Type this: [K####]

The Set Access Key command causes the Interface to recognize only Tags that have been programmed with the same 4-digit access key, and this can only be done transparently using an RFID, Inc. Programmer. The access key is an integral part of the Interface's user-transparent, error detection field so that a Tag programmed with anything other than the set access key will not be recognized at all. The four hexadecimal digits allow 65,536 different series of Tags to exist that cannot be read from one system to another. This feature is used mainly for security and access control applications. Default access key is FFFF.

The data field must consist of 4 hex digits, 0 - F. If the alphanumeric digits A, B, C, D, E, or F are used they must be upper case. If other than 4 valid hexadecimal data characters are received by the Interface, an Invalid Command message will be issued and the current Access Key value will be left unchanged.

SYSTEM RESET COMMAND - [S]

Type this: [S]

The System Reset command causes the Interface to perform a software reset clearing all buffers, reverting to all default settings per jumpers at P3 and P4, setting the access key to its default value FFFF, enabling all Readers, and issuing the power up message. Any previously reported Tags that are still in Reader Antenna range will be reported again.

3.6 INTERFACE RESPONSES

3.6.1 TAG DATA

RFID, Inc. Tags can be programmed with 8 or 16 characters, but 16 characters is used herein:

A Tag will report as <LF># xxxxxxxxxxxxxxxx<CR> where the # symbol represents the Reader address where the Tag was detected, followed by an ASCII space.

In the case of an 8 character Interface Model 2022/8, Tags may only be programmed with the ASCII representations of 0-9 A-D.

In the case of a 16 character Interface Model 2022, Tags may be programmed with the ASCII representations detailed in the Valid Tag Character Set table below, also listing hex value.

@	40	0	30	A	41	P	50
!	21	1	31	B	42	Q	51
“	22	2	32	C	43	R	52
#	23	3	33	D	44	S	53
$	24	4	34	E	45	T	54
%	25	5	35	F	46	U	55
&	26	6	36	G	47	V	56
‘	27	7	37	H	48	W	57
(	28	8	38	I	49	X	58
)	29	9	39	J	4A	Y	59
*	2A	:	3A	K	4B	Z	5A
+	2B	;	3B	L	4C	[	5B
,	2C	<	3C	M	4D	\	5C
-	2D	=	3D	N	4E	]	5D
.	2E	>	3E	O	4F	^	5E
		/	2F	?	3F		

3.6.2 ERROR MESSAGES

In addition to the Power up message, Self-test results, and Tag data previously discussed, the Interface also generates the following messages:

r - Repeat Last Transmission
? - Invalid Command
e - Empty Buffer

All messages out of the Interface are preceded by a Line Feed and followed by a Carriage Return to provide proper screen formatting.

The "r" - Repeat Last Transmission message indicates that the Interface observed a transmission error on the last command received. Since an error was detected the command was not processed and must be repeated by the host.

The "?" - Invalid Command message indicates that the Interface detected a problem with the last command issued. The Invalid Command message is issued upon reception of the End of Message delimiter when one of the following errors has been detected:

> Illegal delimiter format - the receipt of a message not preceded by a start delimiter and followed by an end delimiter.
>
> Illegal command between delimiters - the receipt of a message ot contained within this specification.
>
> Legal but invalid command received - i.e. the receipt of [T] Transfer Request while in Mode 1.

The "e" - Empty Buffer message is issued by the Interface in Mode 2, following a [T] Transfer Request when no Tag has been detected. The Empty Buffer message is issued in Mode 1 when a Repeat Message command is received after the last transmitted Tag has already been replaced in the Interface's Tag buffer by a new Tag.

3.7 WARRANTY

RFID, Inc. products are warranted against defects in materials and workmanship for one (1) year from date of shipment. RFID, Inc. shall, at its option, either repair or replace products that prove to be defective and are returned with freight prepaid to RFID, Inc.'s plant within the warranty period. The foregoing warranty shall not apply to defects resulting from abuse, misuse, accident, alteration, neglect or unauthorized repair or installation. RFID, Inc. shall have the right of final determination as to the existence and cause of the defect.

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