

**MSI-P700 PC/104
IEEE 802.15.4 Wireless
Card with Analog & Digital
I/O
User Manual**

***PC/104 Embedded
Industrial Analog I/O Series***

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I. INTRODUCTION

The MSI-P700 is a low cost, high performance wireless card providing IEEE 802.15.4 protocol using the XBee PRO module operating at an rf frequency of 2.4 GHz. A block diagram of the card is shown in Figure 1. The module is configured to support NonBeacon communications that operate in a Peer-to-Peer network topology not dependent upon the Master/Slave relationships. Modules remain synchronized without use of master/server configurations for rapid synchronization times and fast cold start times. It can also be programmed for NonBeacon mode as either a Coordinator or End Device. The Coordinator mode can be configured to use either direct or indirect transmissions. It will also support Unicast or Broadcast communications.

A 16C550 UART interfaces the XBee module to the PC/104 bus. The UART provides a 16 byte transmit and receive FIFO and baud rates are programmable from 1200 to 115,200 bits/s. Automatic hardware RTS and CTS flow control is used to prevent overflow of the local receiver and remote receiver FIFOs. The card I/O address is jumper selectable for COM1 thru COM4 with an optional 16-bit offset address. Interrupts are jumper selectable for IRQ3 thru IRQ5 and IRQ9 thru IRQ15.

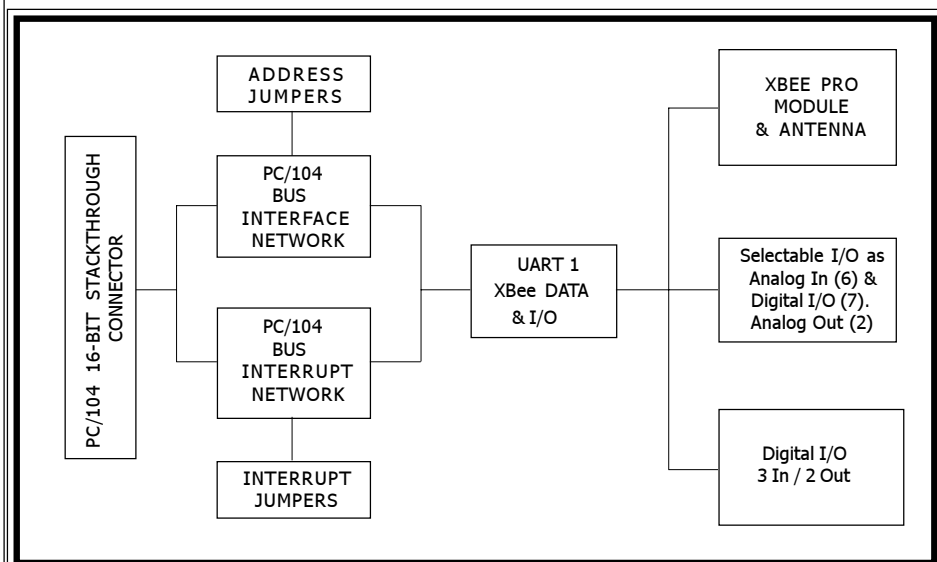


Figure 1. Block Diagram of the MSI-P700.

The XBee I/O provides 6 lines individually selectable as either an analog input (0-5V range, 10-bit resolution) or a TTL input or output, and 1 TTL input. Two XBee analog outputs (0-5V range, 10-bit resolution) are also provided. Unused UART control lines provide 3 input and 2 output TTL lines. All I/O lines have varistor suppressors for surge voltage (lightning, etc.) protection.

The antenna connection to the card is provided by a SMA bulkhead connector. A 6" cable attaches this connector to the rf module which permits its removal from the card bracket for mounting into the user enclosure as an option.

II. HARDWARE DESCRIPTION

A. Card Configuration

The MSI-P700 card is a CMOS design using through-hole and surface-mounted devices. The card configuration is shown in Figure 2 and a circuit diagram of the network is given in Appendix B. The card contains an IBM PC compatible 16C550 UART (U4) that communicates with a XBee Pro 2.4 GHz rf module that provides an IEEE 802.15.4 protocol. Connectors J1, J2 and J3 provide for the XBee digital I/O, XBee analog I/O, and UART digital I/O connections, respectively. J4 is a SMA bulkhead connector for the antenna connection.

Jumper block JP1 is used for address selection and JP2 for interrupt configuration, as described below.

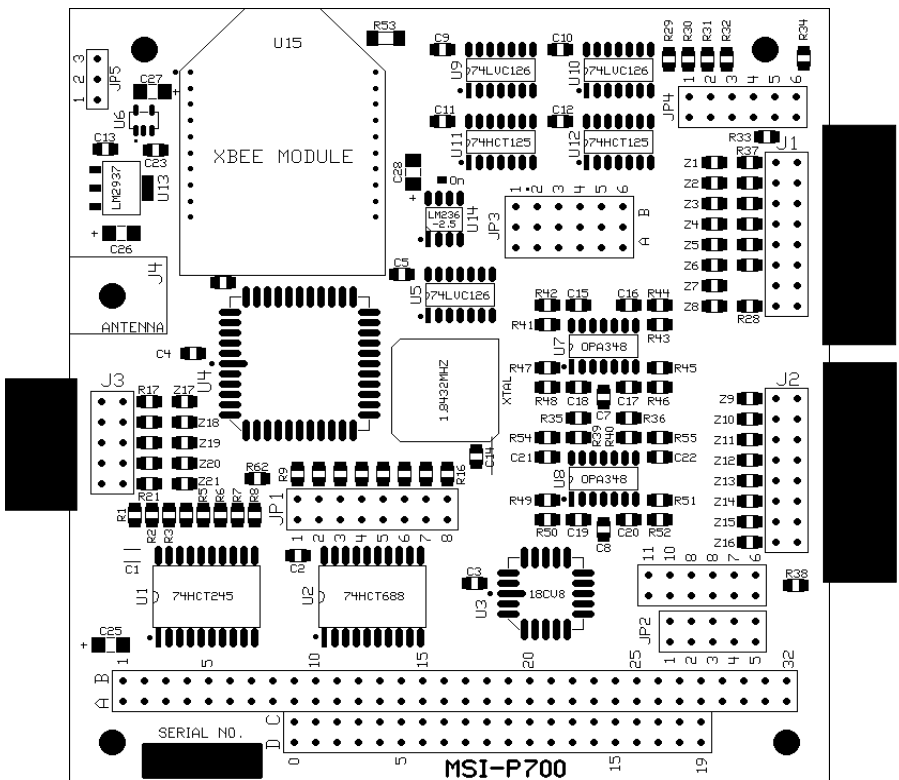


Figure 2. MSI-P700 card outline.

B. Card Addressing

The card address is set by installing appropriate jumpers on JP1, pin pairs 1 thru 8, as shown in Fig. 3. An installed jumper for a given address bit sets the bit to 1 (true) and an uninstalled jumper sets the bit equal to 0 (false).

Addresses A15 thru A10 (JP1-1 thru JP1-6) are jumper selectable for defining the *base address* of the card from 0000H to FC00H on integral 3FFH boundaries, where H denotes a hexadecimal number.

Addresses A8 and A4 (pins JP1-7 and P1-8) permit assigning addresses of COM1 thru COM4, as given in Table 1 for a base address of 0000H.

Table 1. Jumper Selections for COM1 thru COM4.

Address**	JP1-7 (A8)	JP1-8 (A4)	JP1-1 thru 6 (A15-A10)
COM1	ON	ON	OFF
COM2	OFF	ON	OFF
COM3	ON	OFF	OFF
COM4	OFF	OFF	OFF

** COM1 = 3F8H, COM2 = 2F8H, COM3 = 3E8H, COM4 = 2E8H. The base address shown is 0000H (JP1-1 thru JP6 are OFF).

Base addresses selected by installing jumpers on JP1-1 thru JP1-6 are added to the COMx addresses of Table 1.

Example 1. Set a base address of 8000H for COM1.

JP1-1, JP1-7 and JP1-8 are ON. All others are OFF. The absolute address is $8000H + 3F8H = 83F8H$.



Figure 3. Jumper block JP1 address configuration.

Example 2. Set a base address of 3800H for COM3.

JP1-3, JP1-4, JP1-5 and JP1-7 are ON. All others are OFF. The absolute address is 3800H + 3E8H = 3BE8H.

C. Interrupt Connections

Interrupt connections are implemented by jumpers JP2-1 thru JP2-10 as shown in Fig. 4. Jumper selections for selecting interrupts is given in Table 2. The interrupt is enabled by installing a jumper on the desired IRQ. JP2-11 provides a 1K pull-down resistor if it is not provided by the processor card being used.

Table 2. Jumper Selection for Hardware Interrupts.

Interrupt**	Intall Jumper	Interrupt**	Intall Jumper
IRQ2(9)	JP2-1	IRQ10	JP2-6
IRQ7	JP2-2	IRQ11	JP2-7
IRQ5	JP2-3	IRQ12	JP2-8
IRQ4	JP2-4	IRQ14	JP2-9
IRQ3	JP2-5	IRQ15	JP2-10

** Install JP2-11 for 1 KOhm pull-down resistor.

D. XBee Digital I/O

The card provides up to 8 TTL I/O lines consisting of 6 TTL input/output, and 1 TTL input lines. These I/O lines are provided on J1. Their selections are described as follows.

1. XBee TTL I/O lines DIO0 thru DIO5.

The 6 I/O lines DIO0 thru DIO5 are shared with the 6 analog input

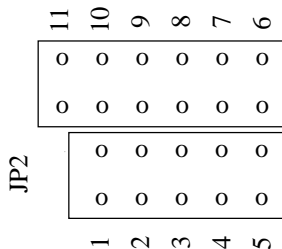


Figure 4. Jumper block JP2 interrupt configuration.

lines of the XBee Pro module. Each line is selectable as analog input , or digital input or output. In the case of a digital selection, the following tasks are required.

- a. Each line must be selected by installing the appropriate jumper on JP4, shown in Fig. 5. These jumpers positions are given in Table 3.

Table 3. Digital Jumper Positions JP4.

Digital Line	Req'd. Jumper	Digital Line	Req'd. Jumper
DIO0	JP4-1,B	DIO3	JP4-4,B
DIO1	JP4-2,B	DIO4	JP4-5,B
DIO2	JP4-3,B	DIO5	JP4-6,B

- b. Each line selected in must be selected as input or output by installing the appropriate jumper on JP5, shownin Fig. 6. These jumper positions are given in Table 4.

Table 4. Digital Jumper Positions JP4.

Digital Line	Req'd. Jumper	Digital Line	Req'd. Jumper
DIO0	JP4-1,B	DIO3	JP4-4,B
DIO1	JP4-2,B	DIO4	JP4-5,B
DIO2	JP4-3,B	DIO5	JP4-6,B

- c. Each line DIO0 thru DIO5 selected must be configured in the XBee Pro module by specifying them as either input or output using the DO thru D5 AT commands with parameters of 3, 4, or 5 (see XBee Pro User Manual). The assignments must match the jumper selections of JP4 and JP5.

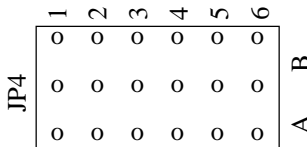


Figure 5. Analog and digital I/O selection jumper block JP4.

2. XBee TTL input line DI8.

The DI8 TTL input line must be selected by installing the jumper JP5-1,2 (factory default). The input must also be enabled for input in the XBee Pro module using the D8 AT command with a parameter of 3 (see XBee Pro User Manual).

3. Digital I/O connections for J1.

Table 5 gives the digital connections for J1. Even pins (2 thru 16) are connected to digital ground and are signal returns for the digital I/O of the odd numbered pins 1 thru 15.

Table 5. Digital I/O Pin Connections for J1.

Digital Line	J1 Pin No.	Digital Line	J1 Pin No.
DIO0	1	DIO4	9
DIO1	3	DIO5	11
DIO2	5	DO8 *	13
DIO3	7	DI8	15

* DO8 is not available in the XBee Pro at this time.

E. XBee Analog I/O

The card provides up to 6 analog inputs, and 2 analog outputs. These I/O lines are provided on J2. The inputs and outputs are 10-bit with ranges of 0 to 5V. Their selections are described as follows.

1. XBee analog inputs AIN0 thru AIN5.

The 6 analog inputs AIN0 thru AIN5 are shared with the 6 digital I/O lines of the XBee Pro module. Each line is selectable as analog input, or digital input or output. In the case of an analog selection, the following tasks are required.

- Each line must be selected by installing the appropriate jumper on JP4, shown in Fig. 5. These jumpers positions are

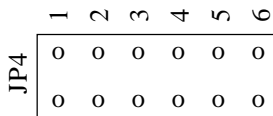


Figure 6. Input/output selection jumper block JP4 configuration.

given in Table 6.

Table 6. Analog Jumper Positions JP4.

Digital Line	Req'd. Jumper	Digital Line	Req'd. Jumper
DIO0	JP4-1,A	DIO3	JP4-4,A
DIO1	JP4-2,A	DIO4	JP4-5,A
DIO2	JP4-3,A	DIO5	JP4-6,A

b. Each input AIN0 thru AIN5 selected must be configured in the XBee Pro module by specifying them as an analog input using the DO thru D5 AT commands with a parameter of 2 (see XBee Pro User Manual). The assignments must match the jumper selections of JP4. The onboard voltage reference should also be selected by the AV AT command with a parameter of 0.

2. XBee analog outputs AOUT0 and AOUT1.

The 2 analog outputs AOUT0 and AOUT1 are derived from the PWM0 and PWM1 functions of the XBee Pro module. These outputs require the P0 and P1 AT commands with a parameter of 2 to specify the PMW mode. The output level is then set by the M0 and M1 AT commands. The parameter used is in the interval of 0 to 0x3FF for output levels from 0 to 5V, respectively.

3. Analog I/O connections for J2.

Table 7 gives the analog connections for J2. Even pins (2 thru 16) are connected to analog ground and are signal returns for the analog I/O of the odd numbered pins 1 thru 15.

Table 7. Analog I/O Pin Connections for J2.

Digital Line	J1 Pin No.	Digital Line	J1 Pin No.
AIN0	1	AIN4	9
AIN1	3	AIN5	11
AIN2	5	AOUT0	13
AIN3	7	AOUT1	15

F. UART Digital I/O

The card provides 3 TTL digital inputs and 2 TTL digital outputs using unused UART control lines. Inputs are associated with the MODEM Status Register (addressed at base address +6) are DSR, DCD and RI for inputs UIN0, UIN1 and UIN2. Outputs are associated with the MODEM Control Register (addressed at base address + 4) OUT0 and OUT1 for outputs UOUT0 and UOUT1. These register relations are summarized in Table 8.

Table 8. UART Registers for TTL I/O.

UART Register	Input	UART Register	Output
DSR	UIN0	OUT0	UOUT0
DCD	UIN1	OUT1	UOUT1
RI	UIN2		

The inputs and outputs are inverted from their register values. For example, if a '1' is written to the OUT0 register, a '0' is output to the output connector pin J3-3.

Table 9 gives the UART TTL I/O connections for J3. Even pins (2 thru 10) are connected to digital ground and are signal returns for the digital I/O of the odd numbered pins 1 thru 15.

Table 9. UART TTL I/O Pin Connections for J3.

Digital Line	J1 Pin No.	Digital Line	J1 Pin No.
UIN0	1	UOUT0	7
UIN1	3	UOUT1	9
UIN2	5		

G. Sleep Mode Configuration

In most applications the sleep mode will not be used since the power required for the PC/104 processor card is large compared to that required for the wireless module. However, JP5 has been provided for routing UART control DTR to the Sleep Request pin of the XBee module. Installing jumper JP5-2,3 connects DTR directly to the Sleep Mode pin. Refer to the XBee Pro User Manual for implementing the sleep modes available.

III. XBee Pro Wireless Module

A. Description

The XBee-PRO OEM RF Modules were engineered to meet IEEE 802.15.4 standards and support the unique needs of low-cost, low-power wireless sensor networks. The modules require minimal power and provide reliable delivery of data between devices. The modules operate within the ISM 2.4 GHz frequency band. The modules have worldwide acceptance as follows:

FCC Approval (USA) Systems that contain XBee-PRO RF Modules inherit MaxStream Certifications.

ISM (Industrial, Scientific & Medical) 2.4 GHz frequency band.

Manufactured under ISO 9001:2000 registered standards.

XBee-PRO RF Modules are optimized for use in the United States, Canada, Australia, Israel and Europe.

The XBee Pro module is a versatile wireless-to-serial interface unit that offers over 75 AT commands for configuring the XBee Pro rf unit and processing data that is transmitted and received between the module and the PC/104 bus of the MSI-P700.

Details for programming of the rf unit and commands for exchanging wireless data is given in the document

XBee_02.15.4.pdf

which is included on this CDROM.

Additional information and up-to-date firmware upgrades can be viewed at the XBee Pro manufacturers web site at

<http://www.digi.com>

IV. SAMPLE BASIC LANGUAGE TEST PROGRAM

The BASIC language program below illustrates software sequences for

- a. Selecting a COMx port , x = 1, 2, 3 or 4.
- b. Setting BAUD rates of 4800 or 9600.
- c. Accessing UART digital I/O ports.
- d. Sending AT commands.
- e. Enabling a receiving mode for displaying of rf data.
- f. Use of the API data command.

The program can be run under DOS using a BASIC interpreter such as QBASIC by Microsoft Corporation. An interpreter can be provided at no charge upon request.

'Terminal program for MSI-P700 with UART port at 9600 BAUD (default mode)

```
COM01 = &H3F8: COM02 = &H2F8: COM03 = &H3E8: COM04 = &H2E8
primary = COM01 `set default for primary port (U4) to COM1
                `using jumpers for JP1-7 & JP1-8.
ComDisplay$ = "COM1"
BRATE% = 9600 `Default BAUD rate.
CLS
PRINT ""
PRINT "Default address is "; ComDisplay$
PRINT "Address jumper JP2-7 should be installed."
PRINT ""; PRINT "Strike any key to continue!"
WHILE INKEY$ = "": WEND
GOSUB init
```

begin:

```
CLS
PRINT ""; PRINT "COM Port = "; ComDisplay$, "BAUD Rate = "; BRATE%
PRINT ""
PRINT "(1) Set COMx (x = 1, 2, 3, 4) port."
PRINT "(2) Set BAUD Rate (4800 or 9600)."
PRINT "(3) Display digital inputs (J3) /IN0 thru /IN2."
PRINT "(4) Set digital outputs (J3) /OUT0 and /OUT1."
PRINT "(5) Enter an AT Command (AT prefix not required)."
PRINT "(6) Enable receiving mode (echoes remote data on screen)."
PRINT "(7) Sends HELLO to remote using API 0x08 identifier."
PRINT "(12) Exit program"
PRINT ""
INPUT "Enter selection - ", GP$
CLS
SELECT CASE GP$
    CASE "1" `Set COMx port
        CLS
```

```

PRINT "": PRINT "Present port = "; ComDisplay$
INPUT "Enter COM port # (1, 2, 3, or 4) = ", x
SELECT CASE x
  CASE 1
    primary = COM01: ComDisplay$ = "COM1"
  CASE 2
    primary = COM02: ComDisplay$ = "COM2"
  CASE 3
    primary = COM03: ComDisplay$ = "COM3"
  CASE 4
    primary = COM04: ComDisplay$ = "COM4"
  CASE ELSE
    primary = COM01: ComDisplay$ = "COM1"
END SELECT

```

```
GOSUB init
```

```
CASE "2" `Set BAUD Rate
```

```

CLS : PRINT "": PRINT "Present BAUD Rate = "; BRATE%
INPUT "Enter New BAUD Rate (4800 Or 9600) = ", BNEW%
PRINT ""

```

```

PRINT "If you have not set the BAUD of the XBee unit to "
PRINT "this BAUD rate, you should use the AT BD command "
PRINT "before you change to this BAUD rate."
PRINT ""

```

```

INPUT "Do you want to change to this BAUD rate? (Y or N) ", q$
IF NOT (q$ = "Y" OR q$ = "y") THEN GOTO start
IF BNEW% <> 9600 AND BNEW% <> 4800 THEN GOTO start
BRATE% = BNEW%
GOSUB init

```

```
CASE "3" `Get digital inputs
```

```
GOSUB getDInputs
```

```
CASE "4"
```

```
CLS : PRINT ""
```

```

INPUT "DOUT0 (0 or 1) = ", DOUT0%: DOUT0% = DOUT0% * 4
INPUT "DOUT1 (0 or 1) = ", DOUT1%: DOUT1% = DOUT1% * 8 + DOUT0%
outbyte% = INP(primary + 4) OR &HC
outbyte% = NOT DOUT1% AND outbyte%
OUT primary + 4, outbyte%

```

```
CASE "5" `Enter Command Mode & send command
```

nextAT:

```
pchar$ = "": PRINT ""
```

```

INPUT "Enter AT Command (w/o AT) = ", Cstring$
Cstring$ = "AT" + Cstring$

```

```
FOR i = 1 TO 3
```

```
  outchar$ = "+": GOSUB sendchar
```

```
NEXT i
```

```
DO
```

```
  GOSUB getchar
```

```
LOOP WHILE pchar$ <> "K"
```

```
DO
```

```
  GOSUB getchar
```

```
LOOP WHILE inchar <> 13
```

```
GOSUB sendstring `send string and await echo
```

```
Cstring$ = "ATCN"
```

```
GOSUB sendstring `send string and await echo
```

```

PRINT "": PRINT "Enter Esc key to go to Main Menu."
DO
    x$ = INKEY$
LOOP WHILE x$ = ""
IF CHR$(27) <> x$ THEN GOTO nextAT
CASE "6" `Display received characters
    DO
        GOSUB getchar1
    LOOP WHILE INKEY$ = ""
    WHILE INKEY$ = "": WEND `Delay for screen freeze
CASE "7" `send hello to remote
    CLS
    outchar = &H7E: GOSUB sendchar1
    outchar = 0: GOSUB sendchar1
    outchar = 10: GOSUB sendchar1
    achk = &HFF
    outchar = 1: GOSUB sendchar1
    outchar = 44: GOSUB sendchar1
    outchar = &H12: GOSUB sendchar1
    outchar = &H34: GOSUB sendchar1
    outchar = 1: GOSUB sendchar1
    outchar = ASC("H"): GOSUB sendchar1
    outchar = ASC("E"): GOSUB sendchar1
    outchar = ASC("L"): GOSUB sendchar1
    outchar = ASC("L"): GOSUB sendchar1
    outchar = ASC("O"): GOSUB sendchar1
    achk = achk AND &HFF
    outchar = achk: GOSUB sendchar1
    DO
        GOSUB getchar1
    LOOP WHILE INKEY$ = ""
CASE "12"
    END
END SELECT

```

start:

```

CLS
GOTO begin

```

sendstring: `send command string

```

pchar$ = "": count = 0
FOR i = 1 TO LEN(Cstring$)
    outchar$ = MID$(Cstring$, i, 1)
    IF outchar$ = "" THEN outchar$ = ",": count = count + 1
    GOSUB sendchar
NEXT i
WHILE (INP(primary + 5) AND &H40) = 0: WEND
OUT primary, 13 `send RET
WHILE (INP(primary + 5) AND &H40) = 0: WEND
FOR q = 0 TO 10000
    GOSUB getchar
NEXT q
RETURN

```

```

init:  `init MSI-P700 port of U4
      OUT primary + 3, &H80`set DLAB = 1
      IF BRATE% = 9600 THEN div = 12 ELSE div = 24
      OUT primary, div: OUT primary + 1, 0
      OUT primary + 3, 3  `8 data, no parity, 1 stop
      OUT primary + 2, 7
      FOR i = 0 TO 15: x = INP(primary): NEXT i `clear receiver buffer
      RETURN

sendchar: `Send character outchar$ to primary port
          WHILE (INP(primary + 5) AND &H40) = 0: WEND
          OUT primary, ASC(outchar$)
          GOSUB getchar
          RETURN

sendchar1: `Send character outchar to primary port
          WHILE (INP(primary + 5) AND &H40) = 0: WEND
          OUT primary, outchar
          GOSUB checksum
          RETURN

getchar:
      IF (INP(primary + 5) AND 1) = 1 THEN
          pchar$ = inchar$
          inchar = INP(primary)
          inchar$ = CHR$(inchar)
          PRINT inchar$;
      END IF
      RETURN

getchar1:
      IF (INP(primary + 5) AND 1) = 1 THEN
          inchar = INP(primary)
          IF inchar = &H7E THEN PRINT ""
          PRINT HEX$(inchar); " ";
      ` GOTO getchar1
      END IF
      RETURN

setDOutput: `set OUT1_BUFFERED (J1) &h55 or &haa
            IF z = 1 THEN `set OUT1_BUFFERED (J1-1,3) = 0,1
                z = INP(primary + 4) `get MODEM control register contents
                z = z OR 4 `set corresponding OUT1 bit in z
                z = z AND (NOT 8)
                OUT primary + 4, z `output to Modem control register
                z = INP(secondary + 4) `get MODEM control register contents
                z = z OR 4 `set corresponding OUT1 bit in z
                z = z AND (NOT 8)
                OUT secondary + 4, z `output to Modem control register

            ELSEIF z = 0 THEN `set OUT1_BUFFERED (J1-1,3) = 1,0
                z = INP(primary + 4) `get MODEM control register contents
                z = z AND NOT 4 `reset corresponding OUT1 bit in z
                z = z OR 8

```



```

OUT primary + 4, z `output to Modem control register
z = INP(secondary + 4) `get MODEM control register contents
z = z AND NOT 4 `reset corresponding OUT1 bit in z
z = z OR 8
OUT secondary + 4, z `output to Modem control register
END IF
RETURN

```

getDInputs: `get digital inputs from /CTS & /DSR of UARTS

```

z = INP(primary + 6) AND &HE0 `get DSR, DCD, RI of primary UART
CLS `clear screen
PRINT "": PRINT "Digital Inputs from J1": PRINT ""
IF ((z AND &H20) / &H20) > 0 THEN q = 0 ELSE q = 1 `invert DSR bit
PRINT "/IN0 (J3-10) = "; q `display /IN0
IF ((z AND &H80) / &H80) > 0 THEN q = 0 ELSE q = 1 `invert DCD bit
PRINT "/IN1 (J3-8) = "; q `display /IN1
IF ((z AND &H40) / &H40) > 0 THEN q = 0 ELSE q = 1 `invert /RI bit
PRINT "/IN2 (J3-6) = "; q `display /IN2
WHILE INKEY$ = "": WEND `delay until keyboard character entry
RETURN

```

checksum:

```

achk = achk - outchar
RETURN

```

V. SPECIFICATIONS

PC/104Bus 16-bit, stackthrough

XBee PRO Module

Indoor/urban Range:	Up to 300' (100 m).
Outdoor Range:	Up to 1 mile (1.6 km) line-of-sight.
Transmit Power Output:	60 mW (18 dBm) 100mW (20 dBm) EIRP.
Operating Frequency:	2.4 GHz.
RF Data Rate:	250,000 bps.
Receiver Sensitivity:	-100 dBm (1% PER).
XBee Analog Inputs:	6 selectable 10-bit channels, 0-5V range.
XBee Analog Outputs:	2 channels 10-bit, 0-5V.
XBee TTL digital I/O:	1 TTL input and 6 selectable as TTL input or output if not assigned as an analog input.

Serial Port

UART:	16C550
I/O Address:	Jumper selectable as COM1 thru COM4 with an optional 16-bit offset.
Interrupts:	Jumper selectable for IRQ3 thru IRQ5 and IRQ9 thru IRQ15. Selectable 1K pull-down resistors
Digital I/O:	3 TTL Input. 2 TTL Output.

I/O Connectors

XBee Analog I/O:	3M 30316-5002
XBee Digital I/O:	3M 30316-5002
UART Digital I/O:	3M 30310-5002

Option Jumpers

.025" square posts, 0.1" grid

Electrical & Environmental

+5V @ 70 mA typical, idle/receive mode

+5V @ 205 mA typical, transmit mode (10 dBm)

+5V @ 285 mA typical, transmit mode (18 dBm)

+5V @ 45 mA typical, power save mode

Operating Temperature: -40° to 85° C

Ordering Information

MSI-P700 AIO & DIO w/RPSMA bulkhead

MSI-P700-X Excludes I/O w/RPSMA bulkhead

Accessories

MSI-WiPort-Ant

Omni-directional "Rubber Duck" antenna,
2.4 GHz, 3 dBi, Reverse Polarity SMA.

APPENDIX

Schematic Diagrams of the MSI-P700

1) P700-1.sch - Schematic sheet 1 of 3.

See p700-1.pdf

2) P700-2.sch - Schematic sheet 2 of 3.

See p700-2.pdf

3) P700-3.sch - Schematic sheet 3 of 3.

See p700-3.pdf