Embedded low power radio modem

MU-1 434MHz

Operation Guide

Version 1.0 (Jun. 2004)

Contents

Chapter 1 The MU-1

1.1 Outline

The low power radio modem MU-1 for embedding in equipment is a radio modem for transmission of serial data. Using a simple system of commands, the user can concentrate on designing the transmitting and receiving protocols for the data using the commands, without needing to be aware of the control system of the radio component.
By using a UART*[1] interface with a single-chip CPU, or a RS232 format interface for computers as the interface for transmitting and receiving data and for issuing commands, it is possible for the user to develop systems quickly.
In addition, it is designed to minimize design difficulties involving the high frequency components in the user system.

The MU-1 meets the requirements of the European R&TTE Directive, and since it carries the CE mark, the user can embed it in their equipment with peace of mind.

　*1 UART (Universal Asynchronous Receiver Transmitter)

☞ **Important**
　Equipment connected with a cable in existing systems cannot simply be replaced with the MU-1.
　The hardware and software must be designed specifically for the MU-1.

■ **1.1.1 Features**

> ➢ Serial data can be transmitted with a simple system of commands
> ➢ Offers a wide communication range with stable operation
> ➢ The transceiver function is incorporated within a compact unit
> ➢ Ideal for battery operated applications thanks to operation at low voltage and low consumption current
> ➢ Uses the UART interface commonly available with on-board CPUs
> ➢ The high frequency circuit is designed specifically as an embedded radio unit, to operate stably on the user system circuit board.
> ➢ Flexible link related IDs (User ID, Group ID, and Equipment ID) required for building 1:1, 1:N, and N:N systems are provided
> ➢ Meets the requirements of the European R&TTE Directive, and comes with the CE mark

■ **1.1.2 Applications**

> ➢ Serial data transmission
> 　Energy monitoring, data monitoring devices, handy terminals, barcode readers
>
> ➢ Telecontrol
> 　Remote control for construction machinery, display devices, motor control, lifters
> 　Remote control of FA equipment
>
> ➢ Telemetry
> 　Water level monitors for rivers and dams, temperature and humidity gauges, rain gauges, pressure gauges, voltmeters, ampere meters

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1.2 Block Diagram

MU-1 Block Diagram

Note
MCF: Monolithic Crystal Filter
SAW: Surface Acoustic Wave
LNA: Low Noise Amplifier

PA: Power Amplifier
PLL: Phase Locked Loop
VCO: Voltage Controlled Oscillator

λ/4 Antenna

RF

433.2000MHz~ 434.7750MHz

SAW Filter BPF

RF Switch

LNA

Down Converter

BPF MCF

21.7MHz±7.5kHz

IF AMP Quad detector

BPF

450kHz

20.945MHz

LPF

Data Slicer

DEMOD. DATA

RXD

RSSI

AD Port

Control CPU

RESET IC

AF-MON   3

RSSI   4

Port — TX-LED   5

Port — RX-LED   6

Port — RX-MON   7

RESET — RESET   8

Port — INI   9

411.5000MHz~ 413.0750MHz

RF Switch

RX VCO

PLL ~1200MHz

CLK, DATA, LE, LD

Temperature revision Xtal 20.945MHz

Ports

Port — MODE   10

Port — CTS   11

Port — RTS   12

RXD — RXD   13

TXD — TXD   14

433.2000MHz~ 434.7750MHz

PA

SAW Filter BPF

Up Converter

IF OSC 21.7MHz

LPF

MOD. DATA

TXD

Ports — EEPROM

VCC for Digital parts

VCC   2

Regulator

FET Switch

2.8v for TX parts

2.8v for RX parts

GND   1

Port   Port

TXSEL

RXSEL

1.3 Example of the Control Method

The VCC terminal of the MU-1 is connected directly to the power source of the mounted CPU. Ensure that the voltage of the power supply is regulated to within DC +3.0 v to +5.0 v.
3-line control can be used without RTS or CTS hardware flow control. In this case, care is required with the timing of transmitting and receiving.
Example 1 and Example 2 are basically the same methods except for the difference in control voltage.

■ 1.3.1 Example 1: The MU-1 is controlled by the on-board CPU

1. It is possible to interface the MU-1 directly using the UART interface of the on-board CPU.
2. As the MU-1 unit is designed to exploit the characteristics of the high frequency component fully, design of the user's circuit board is made easier.
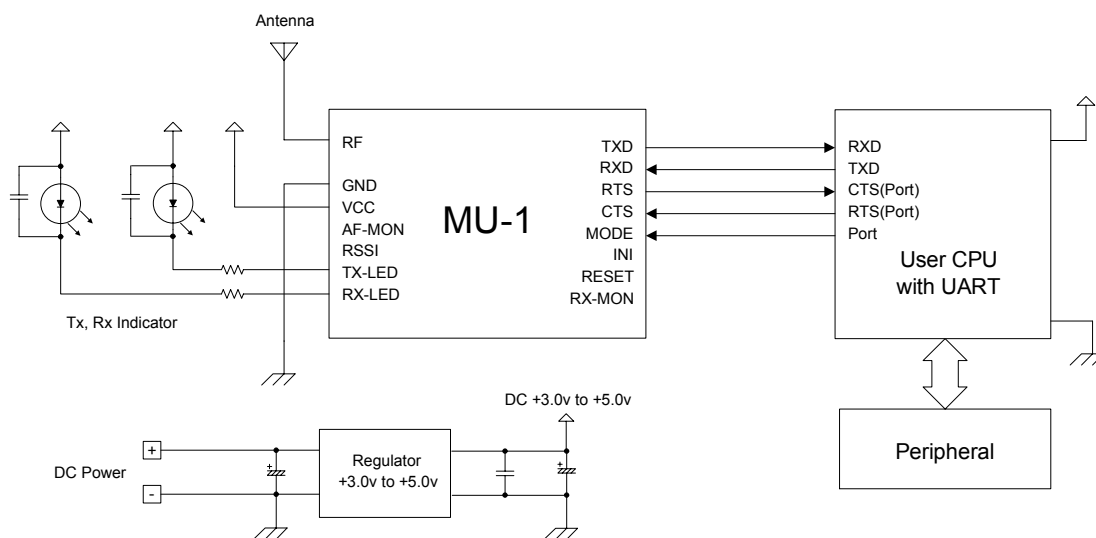
■ 1.3.2 Example 2: The MU-1 is controlled via RS232C

1. Using the RS232C port of your computer, you can develop a program for OS's such as Windows and the like. In this case, use a RS232C transceiver. (The program for existing system equipment will not work.)
2. By supplying power to the MU-1 with a cable, you can also isolate the radio component from your system and locate it in the most suitable environment.
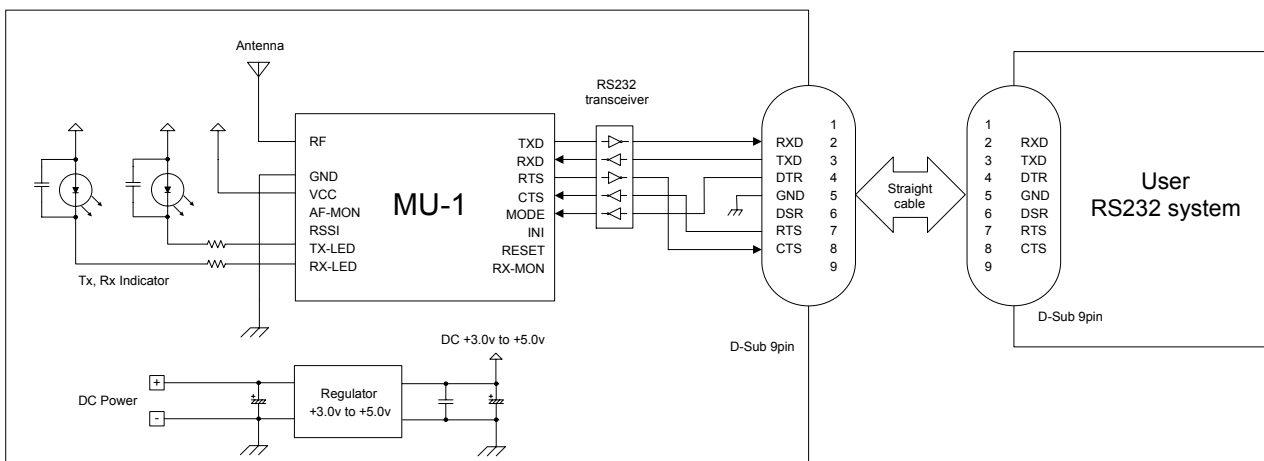
Chapter 2 Specifications and Diagram

2.1 Main Specifications

■ 2.1.1 General specifications

Item	Specification	Unit	Remarks
Standard	R&TTE Directive EN1999/5/EC		CE mark acquired
Emission class	F1D	-	
Antenna power	Within 8 +20% -50%	mW	Contact (50 Ω)
Frequency stability	Within ±4	ppm	-10 ºC to +55 ºC
Antenna	1/4λ wire antenna		Gain of 2.14 dBi or less
Communication method	Half-duplex		
Modulation system	Binary FSK	-	
Oscillation system	PLL synthesizer system	-	
Radio data speed	9,600	bps	
Frequency range	433.2000 to 434.7750	MHz	
Number of channels	64	-	Channel span 25 kHz
Receiver spurious radiation	Less than -60	dBm	
Receiver sensitivity	-108	dBm	Packet error rate 0.1% (255 bytes/1 packet)
Operating temperature	-20 to +60	ºC	The range varies with the temperature conditions.
Operating voltage	3.0 to 5.0	V	Absolute maximum rated voltage 5.5 v
Consumption current	Transmitting: 46 / Receiving: 32	mA	When the supply voltage is 3 v
Number of EEPROM conversions	100,000	times	Data storage time: About 10 years
External dimensions	50 × 30 × 9 (W × D × H)	mm	Not including the antenna. H is the height from the mounting surface.
Unit weight	23.5	g	

Reference data
* Effective radio communication speed: About 6,800 bps / Conditions: One-way communication, no error correction, 25 ºC
* Range: About 600 m / Conditions: One-way communication, no error correction, 25 ºC, line of sight distance, ground level of 1.5 m, vertical antenna
* 12 dB/SINAD receive sensitivity: -119 dBm / Conditions: Measured at the AF-MON terminal, 1 kHz Dev = ±2.0k CCITT FILTER

■ **2.1.2 UART interface specifications**

Communication method	Serial communication (RS232C format)
Synchronization	Asynchronous
Data speed	1,200 / 2,400 / 4,800 / 9,600 / 19,200 / 38,400 / 57,600 bps
Flow control	RTS/CTS hardware flow control
Other parameters	Data length 8 bits, no parity, 1 or 2 stop bits

2.2 Terminal Specifications

◇ The MU-1 transmits user data in serial data format using the UART input/output port (TXD terminal and RXD terminal).

◇ Level conversion is required for connection to RS232. The RS232C DSR signal must be supported by the user's circuit board.

◇ The function of each terminal is shown in the table below. Unused terminals should be set to open.

◇ The control CPU used with this equipment has a CMOS structure.

Termina No.	Terminal name	I/O	Description	Internal circuit
-	RF	I/O	The antenna terminal.	
1	GND	I	GND	
2	VCC	I	The power supply terminal. Provide a regulated power source with a supply voltage of DC +3.0 V to +5.0 or less. Applying a voltage higher than the rating will damage the semiconductor of the unit.	
3	AF-MON	O	A test terminal for monitoring the demodulation signal with an oscilloscope. Normally nothing should be connected to this terminal.	
4	RSSI	O	The received signal strength indicator output terminal for testing. Normally nothing should be connected to this terminal.	
5	TX-LED	O	The terminal for the transmission monitor LED. On when data is transmitted. The signal line includes an internal 1 kΩ resistor. With external resistors, ensure that the LED current is within 1 mA. In addition, add a 470 pF multilayer ceramic capacitor in parallel with the LED.	
6	RX-LED	O	The terminal for the receiving monitor LED. On when valid data is received. The signal line includes a 1 kΩ internal resistor. With external resistors, ensure that the LED current is within 1 mA. In addition, add a 470 pF multilayer ceramic capacitor in parallel with the LED.	

Terminal No.	Terminal name	I/O	Description	Internal circuit
7	RX-MON	O	A test terminal for monitoring the internal status with an oscilloscope when receiving data. Normally this should be open, and should not be used.	
8	RESET	I	The CPU reset terminal. Setting this terminal to Low level for a period of 1 ms resets the internal CPU. This should normally be set to open.	
9	INI	I	The terminal for initializing the CPU internal settings. The settings are initialized if the power is turned on in the Low state. The default values are enabled when the power is switched on again.	
10	MODE	I	Switches between the command mode, binary mode, or text mode. In the command mode when set to High, and the binary mode or text mode when set to Low.	
11	CTS	I	The hardware flow control signal input terminal. Determines that the unit is not busy when the status is Low, and sends data from the TXD terminal. Determines that the unit is busy when the status is High, and does not send data.	
12	RTS	O	The hardware flow control signal output terminal. If the internal status is not busy, the status is Low and data can be received by the RXD terminal. If the internal status is busy, the status is High and data cannot be received.	
13	RXD	I	The serial data receive terminal.	
14	TXD	O	The serial data transmit terminal.	

* The terminal specifications may change without prior notice.

2.3 Channel Table

The frequency channels that the MU-1 can use are channels 0 to 63 in the 434 MHz band.
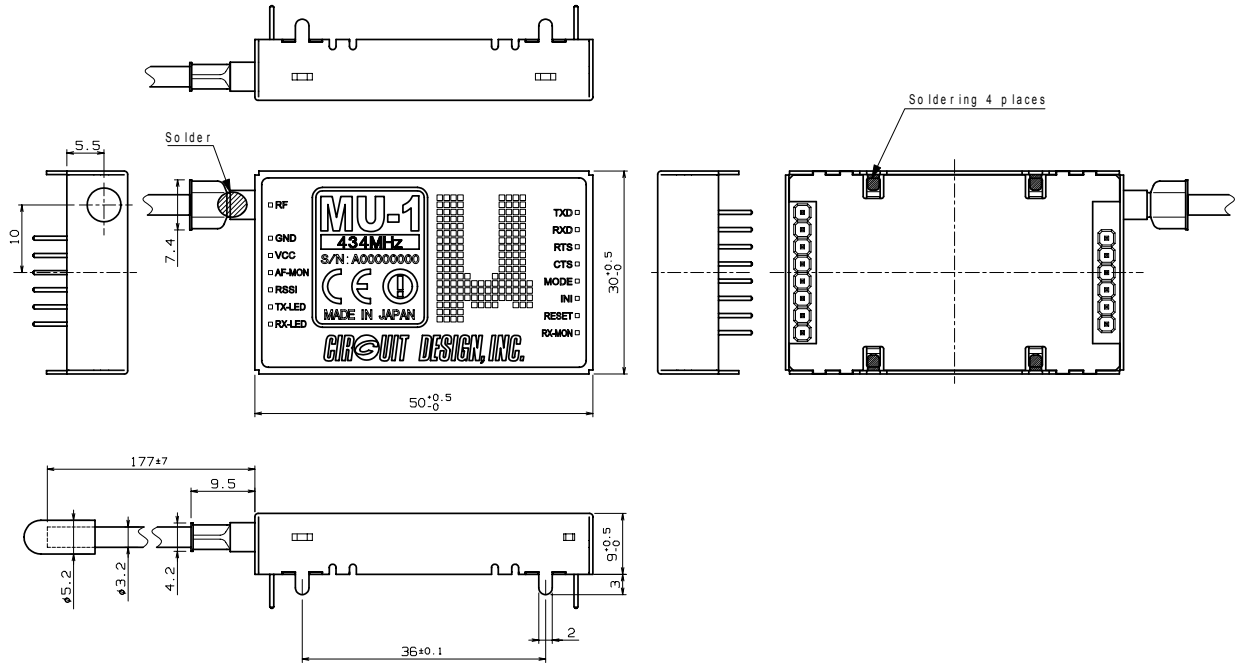To set the channel, use the command format '@CH + channel number'.

Example: Set channel 31 as the channel to use.
  Specify the channel following '@CH' with 2 ASCII (hexadecimal) characters.

Command to the MU-1:   @CH1FC$_{R}$L$_{F}$
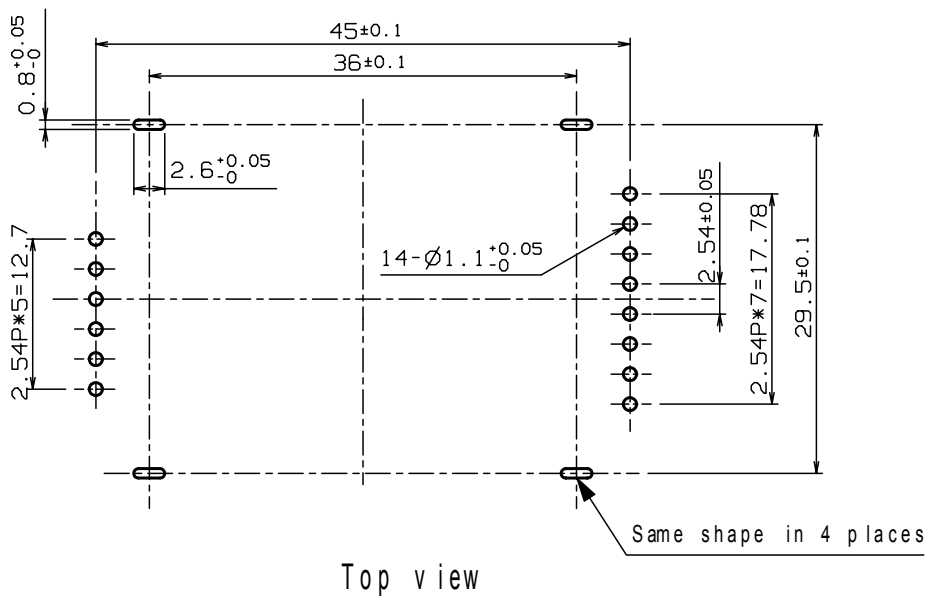
 Response from the MU-1:   *CH=1FC$_{R}$L$_{F}$

▨ : Default channel

MU-1 434 MHz					
Channel	Frequency	Channel	Frequency	Channel	Frequency
Dec. (Hex)	MHz	Dec. (Hex)	MHz	Dec. (Hex)	MHz
0 (00)	433.200	22 (16)	433.750	44 (2C)	434.300
1 (01)	433.225	23 (17)	433.775	45 (2D)	434.325
2 (02)	433.250	24 (18)	433.800	46 (2E)	434.350
3 (03)	433.275	25 (19)	433.825	47 (2F)	434.375
4 (04)	433.300	26 (1A)	433.850	48 (30)	434.400
5 (05)	433.325	27 (1B)	433.875	49 (31)	434.425
6 (06)	433.350	28 (1C)	433.900	50 (32)	434.450
7 (07)	433.375	29 (1D)	433.925	51 (33)	434.475
8 (08)	433.400	30 (1E)	433.950	52 (34)	434.500
9 (09)	433.425	31 (1F)	433.975	53 (35)	434.525
10 (0A)	433.450	32 (20)	434.000	54 (36)	434.550
11 (0B)	433.475	33 (21)	434.025	55 (37)	434.575
12 (0C)	433.500	34 (22)	434.050	56 (38)	434.600
13 (0D)	433.525	35 (23)	434.075	57 (39)	434.625
14 (0E)	433.550	36 (24)	434.100	58 (3A)	434.650
15 (0F)	433.575	37 (25)	434.125	59 (3B)	434.675
16 (10)	433.600	38 (26)	434.150	60 (3C)	434.700
17 (11)	433.625	39 (27)	434.175	61 (3D)	434.725
18 (12)	433.650	40 (28)	434.200	62 (3E)	434.750
19 (13)	433.675	41 (29)	434.225	63 (3F)	434.775
20 (14)	433.700	42 (2A)	434.250		
21 (15)	433.725	43 (2B)	434.275		

2.4 Diagram of External Dimensions

MU-1
434MHz
S/N: A00000000
CE
MADE IN JAPAN
CIRCUIT DESIGN, INC.

RF
GND
VCC
AF-MON
RSSI
TX-LED
RX-LED

TXD
RXD
RTS
CTS
MODE
INI
RESET
RX-MON

Solder

Soldering 4 places

5.5
10
7.4
$50^{+0.5}_{-0}$
$30^{+0.5}_{-0}$

177 ± 7
9.5
$\phi5.2$
$\phi3.2$
4.2
36 ± 0.1
2
$9^{+0.5}_{-0}$
3

2.5 Diagram of Dimensions for Hole Positions

45 ± 0.1
36 ± 0.1
$0.8^{+0.05}_{-0}$
$2.6^{+0.05}_{-0}$
$14-\phi1.1^{+0.05}_{-0}$
2.54 ± 0.05
$2.54P*7=17.78$
29.5 ± 0.1
$2.54P*5=12.7$
Same shape in 4 places

Top view

Chapter 3 How to Design a User System

When embedding this unit in a user system, pay due attention to conformity with the regulations, and the design of the board and case.

3.1 Note on Regulatory Compliance

This modem carries the CE mark in accordance with the R&TTE Directive. However when it is used embedded in other user equipment, take into consideration conformity with the following specifications when designing your system. For details, refer to Chapter 8 "Regulatory Compliance".

1. When using the MU-1, it is the user's responsibility to obtain the CE mark for the final product.
2. When selecting frequency channel and making duty cycle program of the MU-1, refer to 8.1.2.1 "Duty cycle and frequency channel".
3. Use the antenna provided.
4. Use the MU-1 within the specified voltage range.
5. In the documentation for the conformity assessment of the final product, state that the MU-1 is embedded in the system.

3.2 Circuit Board Design

1. The power supply used for the MU-1 must be a DC regulated power source, with a voltage span of +3.0 v to +5.0 v. A current of about 43 mA is required when transmitting. Ensure that the voltage of the MU-1 and user system CPU are the same.

Although a regulated voltage is supplied to the internal high frequency component, in order to support the voltages of a variety of user systems, the power supply for the CPU is connected directly to the VCC terminal. For this reason, care is required to achieve the correct voltage range.

2. Add a 1 kΩ resistor or 0.33 µH inductor to the UART related control signal line. This should be inserted close to the connector pins.

3. When attaching this unit to a circuit board, use a double sided circuit board if possible. On the top surface of the board, make a sufficient area beneath the MU-1 the ground pattern (GND plane), and use the bottom surface of the board for signal lines. For an explanation of the reason for this, refer to "The Antenna" below.

4. If the MU-1 power supply line is used jointly with the power supply lines of other circuits in the system (such as the CPU), it may cause malfunctions, and the unit may not perform properly.
For the power supply of the MU-1, always use a separate line from the system power circuit, and install bypass capacitors at the receiving point. The bypass capacitors should be an electrolytic capacitor with a volume of about 220 µF, and a multilayer ceramic capacitor of 470 pF.

5. Add a resistor close to the connector pins of the LED terminal, and limit the LED current to 1 mA or less. This terminal has an internal 1 kΩ resistor in series. If the LED is not sufficiently bright, provide a driver circuit.
Add multilayer ceramic capacitors of about 100 to 470 pF in parallel to the LEDs connected to the TX-LED and RX-LED terminals.

6. Do not connect anything to the AF-MON, RSSI, and RX-MON terminals.

7. Make the signal lines to this unit as short as possible.
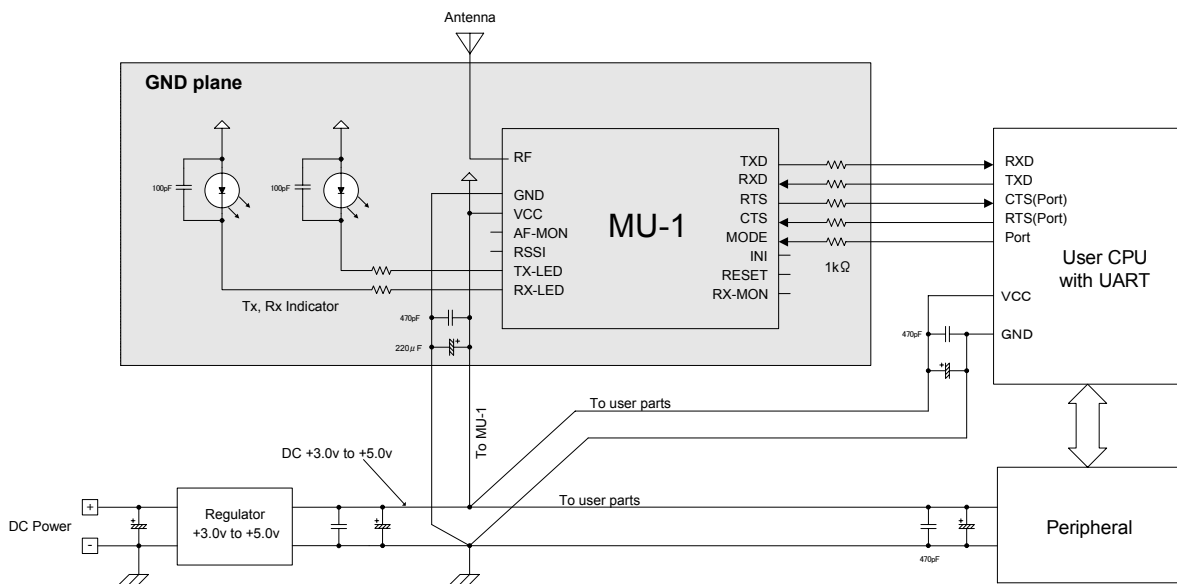
3.3. The Antenna

In systems where a non-directional antenna is required, it is important that the antenna stands vertically in order to exploit the communication performance to the maximum.

Note that if, for reasons peculiar to the equipment, the antenna must be inside the case, communication performance will be very significantly degraded when handled in the following ways, since these methods contravene antenna theory. It is the responsibility of the user to test performance thoroughly when designing equipment.

1. Putting the antenna inside a metal case
2. Wrapping the antenna around the MU-1 itself
3. Locating the antenna beside the ground pattern of your circuit board
4. Fitting the antenna inside by bending it
5. Cutting the antenna to make it shorter

The antenna of the MU-1 is a 434 MHz band 1/4λ whip antenna. Whip antennas are antennas that substitute the ground as one end of a dipole antenna. For this reason the ground has a very important meaning. Although the main unit of the MU-1 has the function of a ground, in order to exploit its performance fully, connect it to the largest possible ground pattern when mounting the MU-1 on your circuit board.

In addition, in the case of two way communication between fixed stations, inclining the whip antenna of the MU-1 forwards may increase its communication range. Carry out tests in the specific environment of use.

3.4 Miscellaneous

1. Devise ways of isolating the MU-1 as far as possible from sources of noise, including from other embedded equipment.
2. Arrange the MU-1 so that it will not be covered by the operator's hand or the like.
3. The MU-1 does not have a waterproof structure. If the antenna is located outside the main unit, use a structure that prevents water droplets from entering the case.

Chapter 4 How to Use the MU-1

4.1 System Configuration

The MU-1 can be used for building 1:1, 1:N, and N:N systems. Several systems can be operated within the same area by separating the channels used.
Equipment IDs from 01h to FEh can be specified, and a maximum of 254 MU-1 units can be connected in 1 group.

Communication within a group (1:N and N:N systems)
Set the same User ID and Group ID for one group. If the Destination ID specified at the master station (transmitting station) and the Equipment ID of the target station (receiving station) match, data is output from the MU-1.
The diagram below shows a 1:N system, although it is also possible to build an N:N system in which all the units have an equal relationship.
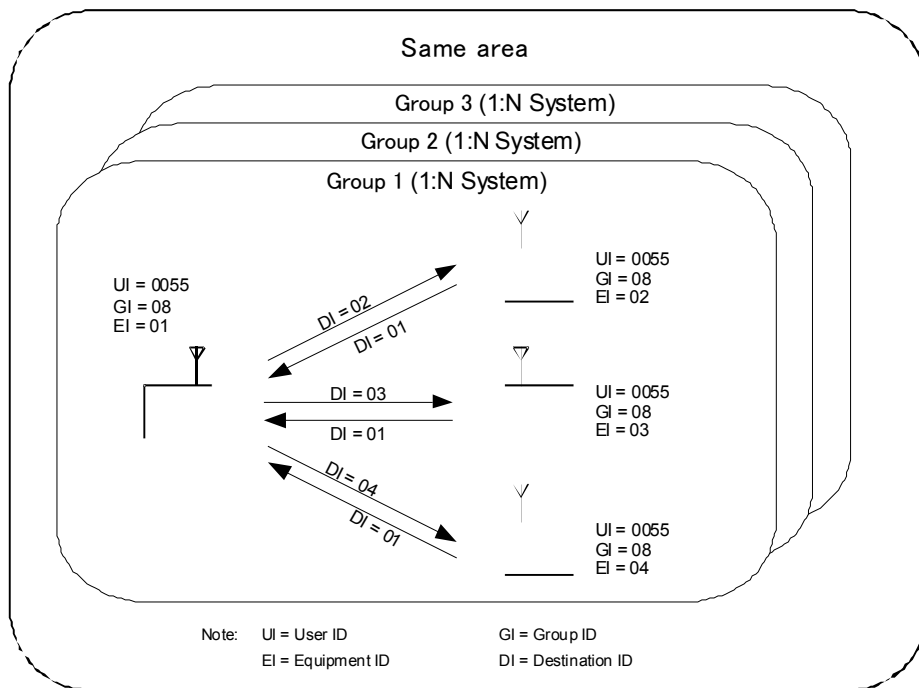
Communication between groups
By changing the Group ID for transmitting, it is possible to communicate with another group.
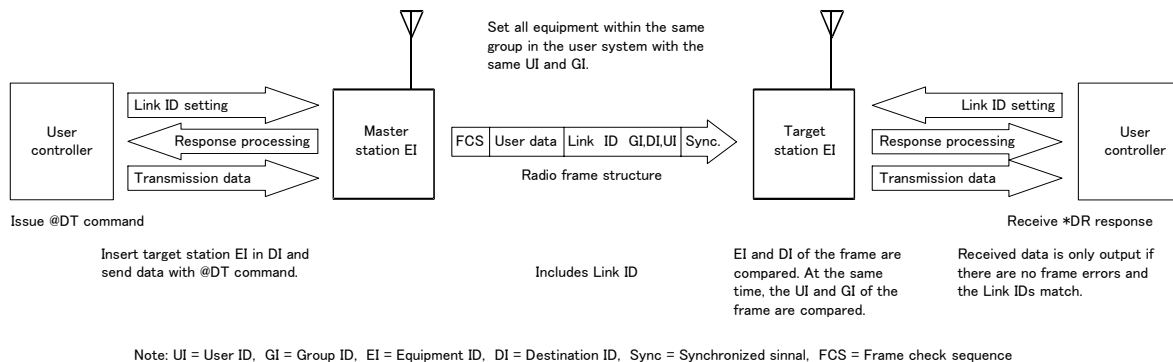
Broadcast communication
If the Destination ID is specified as 00h at the master station and data is transmitted, all target stations will receive the data at the same time, irrespective of the Equipment ID.

4.2 Link ID and Link Conditions

■ 4.2.1 Outline of the transmission process

The diagram below shows an example of the transmission process of the MU-1 in the case of one-way communication.

Note: UI = User ID, GI = Group ID, EI = Equipment ID, DI = Destination ID, Sync = Synchronized sinnal, FCS = Frame check sequence

■ 4.2.2 The Link IDs
In order to transmit and receive data, the MU-1 uses the following 4 types of link related IDs.
Link IDs can be specified easily with commands, and they can be changed each time a data frame is sent.

1. UI: User ID, 16-bit, 0000h to FFFEh (0000h is the ID for testing, and FFFFh cannot be used)
    The User ID is an ID given to the MU-1 user for identification of the user system. Communication is not possible unless all equipment within the user system is set with the same User ID. The product default User ID is 0000 and this can be used as it is when no particular User ID is required. However, we recommend that you set a User ID to prevent radio interference within a given area. If you require a User ID, please contact the distributor or Circuit Design, Inc.

2. GI: Group ID, 8-bit, 00h to FFh
    Set the same Group ID for all equipment within the group.
    Maintain Group IDs as identification numbers when building other systems.
    Please contact Circuit Design, Inc. in cases where use of Group IDs is insufficient and you require other User IDs.

3. EI: Equipment ID, 8-bit, 01h to FFh (FFh is a special operation)
    At the master station, enter the Equipment ID of the target station as the Destination ID.
    At the target station, the Destination ID included in the received frame is automatically compared with the local station EI.

4. DI: Destination ID (target station ID), 8-bit, 00h to FFh (00h and FFh are special operations)
    Enter the Equipment ID of the target station with the Destination ID command '@DI'.
    If 00 (DI=00h) is specified as the Destination ID, all equipment within the same group will receive the data at the same time. If DI=FFh is specified, the data is sent but no station will receive it.

■ 4.2.3   Conditions for establishing a link
A link is established for all communications when the following conditions are met simultaneously.
1. There are no errors in the received frame
2. The User IDs and Group IDs match
3. The Equipment ID specified in the Destination ID of the frame and the Equipment ID of the target station match
4. The channel used is the same

4.3 Modes

The MU-1 has the following 3 modes.
1. Command mode (standard mode)
2. Text mode (for testing)
3. Binary mode (for testing)

Transmitting and receiving data is usually performed in the command mode. Use this mode in your application program. The text mode and binary mode are provided as testing modes, however you can also make applications within the range of these functions.

■ 4.3.1 Command mode

This is the basic mode for sending and receiving user data by radio.
The MU-1 commands consist of commands for transmitting and receiving data, and commands for control of the parameters of the MU-1 unit itself.
Control of the radio module is performed automatically by the MU-1, so you do not need to pay attention to this aspect.
When data is received, only correctly received data is output to the user application as a receive response.
255 bytes of user data can be sent at one time.

■ 4.3.2 Text mode

This mode is used to check operation using RS232C communication software (HyperTerminal and the like) on a PC. Text data can be input and output directly. This mode is convenient for transmitting and receiving characters entered using a keyboard.
The input character string (max. 255 characters) is buffered until the C_RL_F code is received, or the buffer is filled with 255 characters and the character string is framed and transmitted.

■ 4.3.3 Binary mode

This mode is used to check operation using RS232C communication software (HyperTerminal and the like) on a PC. All 8-bit codes (00h to FFh) can be transmitted and received as data. 225 bytes of binary data can be input or output directly at one time.
The input character string (maximum 255 characters) is buffered until the buffer is filled with 255 characters, or until the value set for the period during which no data is input is reached, and the character string is framed and transmitted.
The setting for the period during which no data is input is performed with the '@TB' command.

■ 4.3.4 Mode setting

When the MODE terminal is at Low level

1. In the command mode if the '@MDTX' command is issued, the MU-1 mode register is set to 'TX', which is the text mode. Issuing the ESC code returns from the text mode to the command mode.

2. In the command mode if the '@MDBI' command is issued, the MU-1 mode register is set to 'BI', which is the binary mode. To switch from the binary mode to the command mode, turn off the power supply of the MU-1 briefly.
   If the BI mode is fixed in the EEPROM using the command option '/W', the MU-1 cannot be set to the command mode without initializing it.
   To initialize the MU-1, turn on the power while pressing the switch connected to the RESET terminal, and after turning off the power briefly, turn it on again.

3. By setting the MODE terminal to High level, the MU-1 can be set to the command mode whatever the setting in the MU-1 mode register (irrespective of the current mode).

When the MODE terminal is at High level
   The MU-1 is set to the command mode irrespective of the setting in the mode register.

Diagram of the relationship between modes
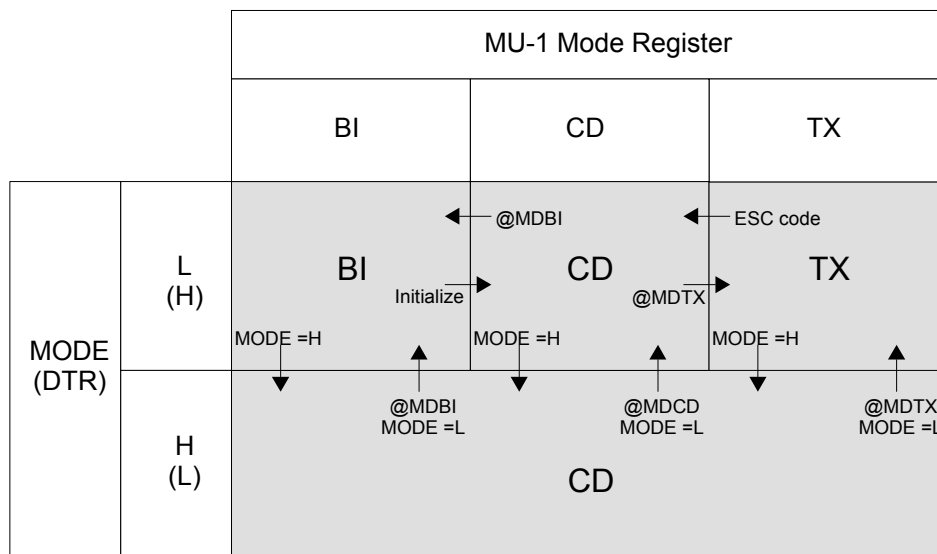
* BI: Binary mode   **CD:** Command mode   **TX:** Text mode

* The brackets ( ) in the diagram indicates use of RS232C. When using HyperTerminal, the DTR line is always at H level and the MODE terminal is at L level.

Chapter 5 How to Develop a Program

Control of the MU-1 is performed by issuing commands and processing the subsequent response (including the data received).
The MU-1 has 3 modes, however the only mode required for making practical applications is the command mode.
The following sections explain the items necessary for developing a user program, focusing on the command mode.

The purpose of the MU-1 is to provide the basic components for communication in order to enable various types of equipment to use radio.
For this reason it is necessary to build communication protocols (MCA, ARQ and so on) into the user application in accordance with the particular application.

5.1 The Operations of the MU-1

1. The radio transmission speed of the MU-1 is fixed at 9,600 bps. Note that this is different from the rate of the UART (RS232C) interface. In addition, to achieve communication, besides the user data, data consists of a frame structure with a preamble, control data, error checking data and so on added. For this reason the effective rate for radio transmission is 6,800 bps.

2. RTS and CTS hardware flow control is used for the serial interface of the MU-1.
   The RTS signal is the output signal from the MU-1 to the user system, and when RTS is Low the MU-1 can receive data.
   When RTS is High, the internal data buffer is full and it cannot receive.
   The CTS signal is the input signal from the user system, and when CTS is Low the MU-1 can output data.
   When CTS is High, data output stops.

3. The modes (command, text, binary) of the MU-1 are switched as follows.
   a. Switching between the command mode and binary mode
   To switch from the command mode to the binary mode, issue the '@MD BI' command, then set the MODE terminal to Low. To switch from the binary mode to the command mode, set the MODE terminal to High.
   b. Switching between the command mode and text mode
   To switch from the command mode to the text mode, issue the '@MD TX' command, then set the MODE terminal to Low.
   To switch from the text mode to the command mode, set the MODE terminal to High.
   To switch from the text mode to the command mode with the MODE terminal at Low, issue the ESC code (escape code: 1Bh).

4. Operations when the power is turned on
   After the MU-1 is turned on, it takes 100 ms for internal operation to become stable.
   During this interval it cannot receive commands.

5. When transmitting and receiving user data frames, the MU-1 outputs only frame data that is received correctly from UART, and discards frame data that experiences radio transmission errors. There is no response issued for such frames.

5.2   Command Transmission

| ⚠ Caution | Do NOT use commands other than those specifically for the MU-1. |

■ 5.2.1 Issuing commands

It is acceptable to feed the characters of a command such as '@CH03$_{CRLF}$' to UART sequentially.
* @: @ (40h) = prefix C_RL_F: C_R (0Dh) = carriage return, L_F (0Ah) = line feed

a. With the on-board CPU
To issue a command, first prepare the command data, then feed it to the UART 1 byte at a time from the beginning. Since UART applies transmission interrupt with each byte transmitted, ensure that all bytes of the command are transmitted within that routine.
Example: With '@CH20$_{CRLF}$'
As transmission interrupt is applied automatically when the first '@' is sent with discretionary timing, ensure that the next byte 'C' is sent within the transmission interrupt routine. In order to stop transmission interrupt when all the characters within the command have been sent, obtain a suitable command size including a terminator, and keep the number of transmissions within that size.

b. With a program for OSs such as Windows
Feed already prepared command strings to an RS232C processing component or the like.

■ 5.2.2 Issuing data transmission commands (DT)

Example: With the 5-byte transmission data '#%&45'.

   Make the command string '@DT05#%&45$_{CRLF}$'.   * '05' is the data size

First obtain the 2 digit hexadecimal value for the number of bytes of the transmission data (#%&45), and enter the '@DT' command data size component in ASCII characters. The response is '∗DT=05$_{CRLF}$'.

The MU-1 can send data with a size of 255 bytes or less at one time, although internally it has a 255-byte double buffer structure. In addition, although the mode is normally the receive mode, when user data is sent to one side of the buffer, the MU-1 switches to the transmit mode and starts radio transmission. When transmission ends, the MU-1 returns to the receive mode.

If the next user data is sent when user data is being transmitted, the MU-1 does not return to the receive mode and enters the continuous transmission mode. This enables efficient cyclic data transmission and transmission of data that exceeds 255 bytes.
In other words, after sending data with the '@DT' command, and after confirming the '∗DT' response, the MU-1 will always enter the continuous transmission mode if the next data is sent within the time found with the following equation. If this time is exceeded, the MU-1 returns to the receive mode.
          Time for sending the next data = within 5 ms + 1.04 ms × amount of user data

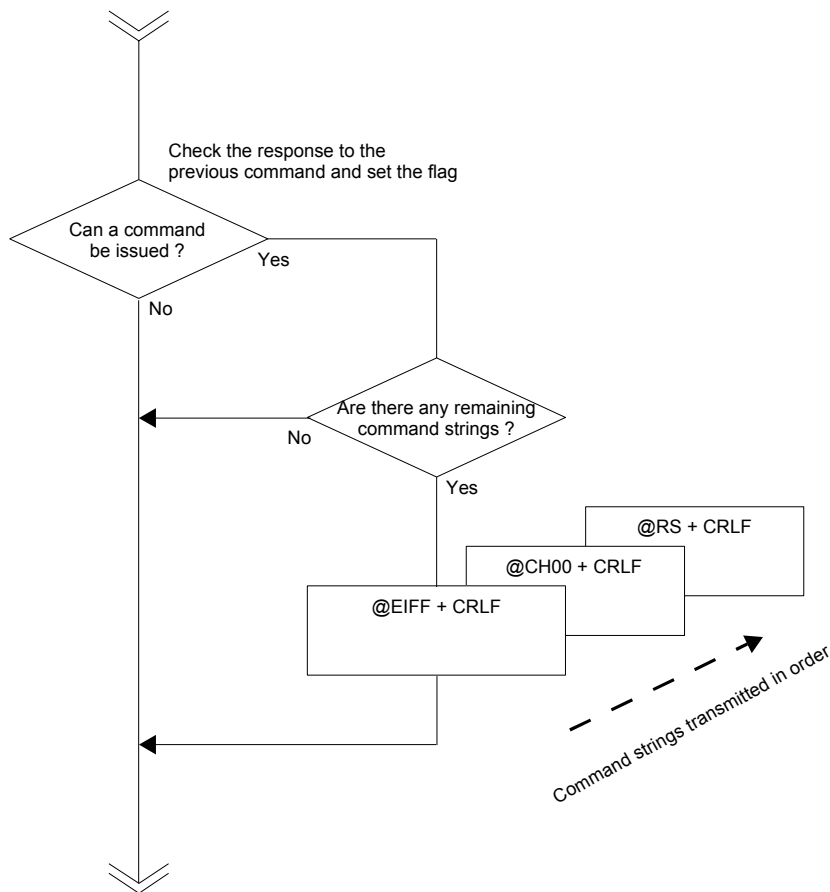* Hardware flow control operates to control sending of the data.

■ 5.2.3 Issuing commands continuously

You cannot issue commands successively as in '@CH03$_{\text{CRLF}}$@EI33$_{\text{CRLF}}$@DI05$_{\text{CRLF}}$'. In other words, there is always one response corresponding to one command, and the next command should not be issued until this response has been confirmed.
The procedure is as follows.

1. Issue the command '@CH03$_{\text{CRLF}}$'.   'Confirm (process) the response '*CH=03$_{\text{CRLF}}$'

2. Issue the command '@EI33$_{\text{CRLF}}$'.   'Confirm (process) the response '*EI=33$_{\text{CRLF}}$'

3. Issue the command '@DI05$_{\text{CRLF}}$'.   'Confirm (process) the response '*DI=05$_{\text{CRLF}}$'

Process for issuing commands continuously

Preparation
1. Create a transmit command string
   Example: @EIFF + CRLF
           @CH00 + CRLF
           @RS + CRLF
2. Set the number of the command string
3. Enable issuing of the command

Check the response to the
previous command and set the flag

Can a command be issued ?
Yes
No

Are there any remaining command strings ?
No
Yes

@RS + CRLF
@CH00 + CRLF
@EIFF + CRLF

Command strings transmitted in order

■ 5.2.4 Issuing commands continuously (when ignoring the response)

As shown in the timing diagram in Chapter 7, a response is returned for each command after a certain period of time has elapsed.
It is possible to issue commands continuously by ignoring the responses and inserting a wait routine between each command. When using this method, allow plenty of extra time, and test the system thoroughly before commercializing the product.

5.3 Response Processing

■ 5.3.1 Responses

Responses are returned by the MU-1 in the following cases.
1. When a command is issued (transmit response, control response, error response)
2. When data is received from other radio equipment within the system (receive response = '@DR response')

■ 5.3.2 Response structure

All responses start with the prefix '*', and the control response name is the same 2 ASCII characters as the corresponding command. The 'DR' response is the response indicating the transmitted data, and it corresponds to the transmitting end 'DT' command.
After the 2 character response name comes '=', followed by bytes that indicate a parameter, value or data.
At the end of the response, the 2 character terminator $C_{R}L_{F}$ (0Dh, 0Ah) is appended.

Example: *CH=1B$C_{R}L_{F}$ *EI=30$C_{R}L_{F}$ *DR=0B66666666666$C_{R}L_{F}$

■ 5.3.3 Response types

Responses consist of the following 3 types, and each type must be processed separately.

1. 2 character response: The response parameter is a 2 character response
   GI, EI, DI, DT, CH, RS, MD, BR, SB, PB, TC, TB, CT, RM, VR, ER, SG, IR
   Example: Command '@CH2A'   Response: '*CH=2A'
   The value '2A' consists of 2 ASCII characters that express a hexadecimal number.

2. 4 character response: The response parameter is a 4 character response
   UI
   Example: Command '@UI800F,xxxx' Response: '*UI=800F$C_{R}L_{F}$'
   The value '800F' consists of 4 ASCII characters that express a hexadecimal number.

3. DR response: Response when data is received
   Example: Receive response when 10 values (0Ah) are received.
      '*DR=0A5555555555$C_{R}L_{F}$'
   The value '0A' consists of 2 ASCII characters that express a hexadecimal number.
   After the data size comes the corresponding number of bytes of data.

■ 5.3.4 Response processing

First, the response data that enters UART from the MU-1 is received by the ring buffer. If there is data in the ring buffer, the response identification routine takes 1 byte at a time and performs interpretation of the response. After, the processing routines diverge in accordance with each response.
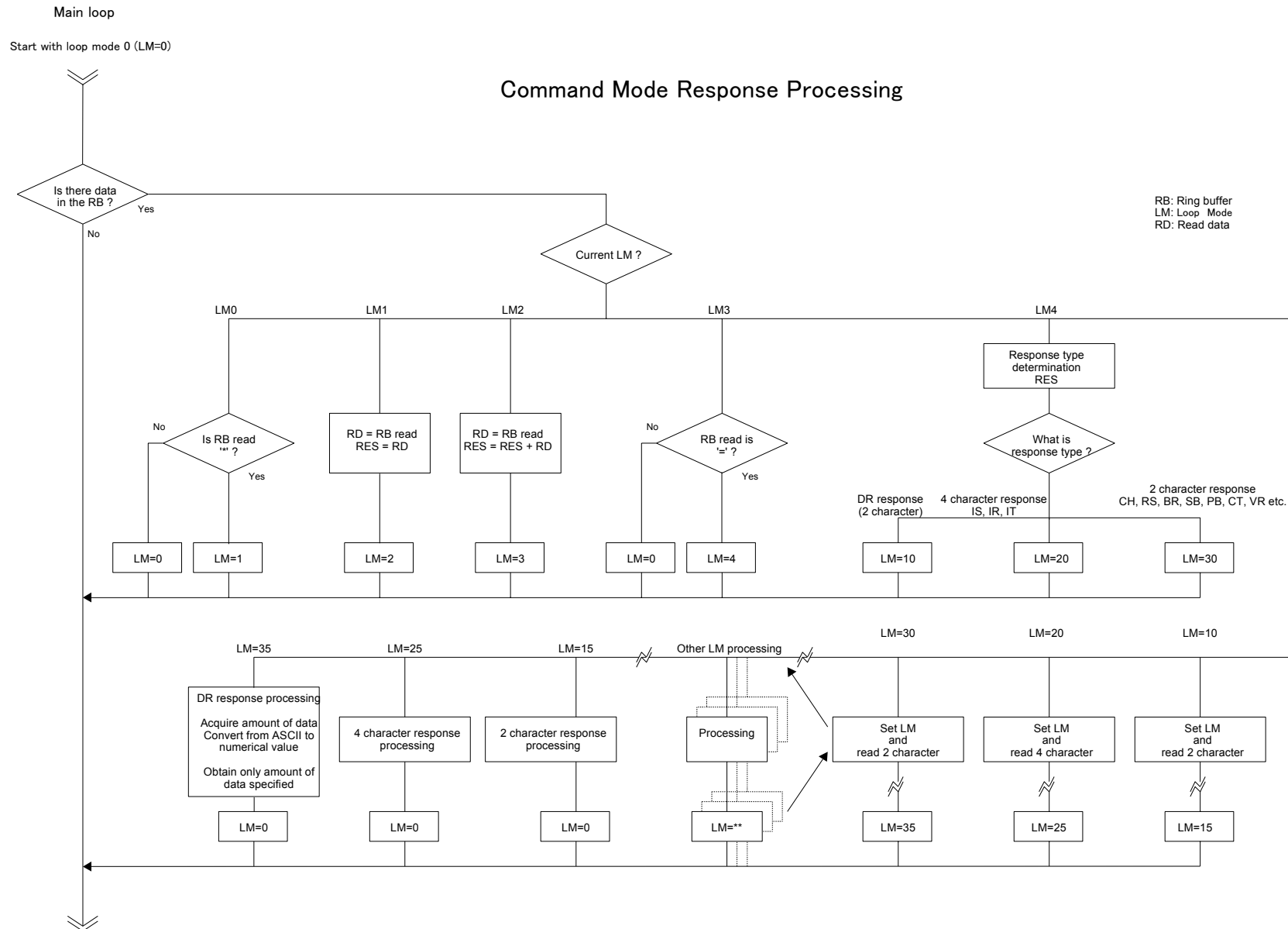
To determine the response type, prepare a table of responses, and make a comparative judgement. It is convenient to return the result of comparison as an integer of the response position on the table, and for the value to diverge to the processing routine.
Arrange the responses in the table divided into groups by type.
Example:
  array ['DR', 'UI', 'GI', 'EI', 'DI', 'DT', 'CH', 'RS', 'MD', 'BR', 'SB', 'PB', 'TC', 'TB', 'CT', 'RM', 'VR', 'ER', 'SG', 'IR']

Response values are ASCII strings that express a numerical value, so when using values, provide a routine to convert the ASCII characters into numerical values. For example, when data is received, the DR response value indicates the amount of user data received, so this is converted to a numerical value and only that amount of data is obtained.

Main loop

Start with loop mode 0 (LM=0)

Command Mode Response Processing

RB: Ring buffer
LM: Loop Mode
RD: Read data

Is there data in the RB ?

Yes

No

Current LM ?

| LM0 | LM1 | LM2 | LM3 | LM4 |

Response type determination RES

Is RB read '*' ?

No

Yes

RD = RB read
RES = RD

RD = RB read
RES = RES + RD

RB read is '=' ?

No

Yes

What is response type ?

DR response (2 character)

4 character response IS, IR, IT

2 character response CH, RS, BR, SB, PB, CT, VR etc.

| LM=0 | LM=1 | LM=2 | LM=3 | LM=0 | LM=4 | LM=10 | LM=20 | LM=30 |

LM=35

LM=25

LM=15

Other LM processing

LM=30

LM=20

LM=10

DR response processing

Acquire amount of data
Convert from ASCII to numerical value

Obtain only amount of data specified

4 character response processing

2 character response processing

Processing

Set LM and read 2 character

Set LM and read 4 character

Set LM and read 2 character

| LM=0 | LM=0 | LM=0 | LM=** | LM=35 | LM=25 | LM=15 |

5.4 Creating an Air Monitoring Function

The air monitoring function such as the one in the Evaluation Program obtains the RF input level of the receiver and monitors the radio wave status of the field.
The MU-1 can get the RSSI level of the designated channel by issuing the '@RS' command.
The air monitoring function can be achieved by designating a special ID for obtaining the RSSI level as the Equipment ID (EI = FFh), and outputting the RSSI level to the graph-making component and the like while obtaining the RSSI level of each channel sequentially.

* When the Equipment ID of the MU-1 is EI = FFh, the system is reserved so the MU-1 performs special operations. When the Destination ID is DI = FFh, data cannot be transmitted, and when the Equipment ID is EI = FFh, even if the link ID matches, received data is not output. Instead, the RSSI (radio field intensity) of the current channel can be read out with the '@RS' command.

The procedure is as follows.
1. Issue the command '@EIFF'.
   This setting is made only once at the beginning.
2. Issue the command '@CHxx'.
   Designate a channel for which to acquire the RSSI level. 'xx' is the hexadecimal value that indicates the channel.
3. Issue the command '@RS'.
   This acquires the RSSI level.
4. The RSSI level acquired is output as graph components and so on.
5. Repeat steps 2 to 4.

Note: Be sure to confirm the response to the '@CH' command issued first before issuing the '@RS' command.

5.5 Achieving Data Transmission

The MU-1 can send data of 255 bytes or less at one time. When transmitting data in excess of 255 bytes, you will need to incorporate a transmission protocol.
When transmitting and receiving user data frames, the MU-1 outputs only frames that are received correctly, and discards those frames that experience errors. There is no response issued for dropped frames.
When transmitting large volumes of data such as files, transmission is performed using two-way communication such as ARQ (Automatic Repeat Request), in order to provide measures against dropped frames caused by radio communication errors. Data frames include frame numbers and the like, and these are used as the criteria for ARQ.

5.6. Operation in Binary Mode

The binary mode of the MU-1 is intended to be used for test communication. Applications that use the MU-1 should basically use the command mode.
However, it is possible to develop simple applications using the binary mode for applications that send less than 255 bytes at a time, if certain conditions are met. This applies only to newly developed applications and does not mean that data output by existing equipment can be sent as is. In other words, the format, timing, and control lines for output data of existing equipment must match the content of this operation guide.

■ 5.6.1 Modes

First, we will explain about the command mode and binary mode. The diagram below is a relational diagram of the MU-1 modes.
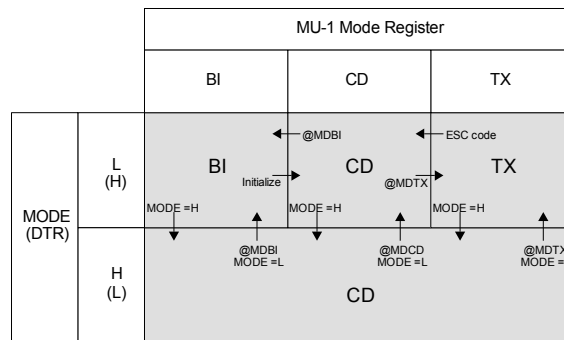
BI: binary mode, CD: command mode, TX: text mode

Command mode
There are two ways to set the MU-1 to the command mode, as follows.
1. If the MODE terminal is set to H, the MU-1 is set to the command mode irrespective of the setting in the MU-1 mode register.
2. If the MODE terminal is set to L, when the power is turned on the MU-1 starts in the default mode set in the EEPROM. Depending on the mode, take the following action.
In the binary mode: Reset the MU-1.
In the text mode: Issue the escape code: 'ESC'.

* Reset method: Turn on the power while pressing the switch connected to the RESET terminal, and turn on the power again.

Binary mode
There are two ways to set the MU-1 to the binary mode, as follows.
1. If the MODE terminal is set to H, set the MU-1 mode register to 'BI' with the '@MDBI' command. Then set the MODE terminal to the L level.
2. If the MODE terminal is set to L, when the power is turned on the MU-1 starts in the default mode set in the EEPROM. Depending on the mode, take the following action.
In the command mode: Set the MU-1 mode register to 'BI' with the '@MDBI' command.
In the text mode: Issue the escape code: 'ESC' and after setting the MU-1 to the command mode, switch modes.

■ 5.6.2 How to use the binary mode (when developing new applications)

The binary mode of the MU-1 can be used in accordance with the following methods, however when it is used in this mode, it must meet the **"Conditions for use of the binary mode"**, explained later.
Set the MODE terminal to be controlled by the CPU.

1. Using the binary mode while switching between the binary mode and command mode
With applications that must change channels and the destination of transmissions, switch between the command mode and binary mode, using the CPU to control the MODE terminal.

### 2. Using only the binary mode directly after turning on the power
If you want to use the MU-1 in the binary mode directly after turning on the power of the system, without changing channels or the destination of transmissions, issue the command "@MDBI/W" to set the MU-1 mode register and to fix the mode in the EEPROM. This setting is made only once at the beginning when first using the system. In addition, when turning on the power, set the MODE terminal to L.
Use the command '/W' option to fix the channel, User ID, Destination ID and so on in the EEPROM.

3. Connection example
This is an example of connection in which hardware flow control is not used.
Normally with the MU-1, in order to prevent buffer overflow of the data buffer, hardware flow control is fixed as the flow control for serial communication. This also applies to the binary mode. However, if the data to send at one time is less than 255 bytes, data can be sent without performing flow control.
In addition, since the various setting commands of the MU-1 are only a few bytes, there is no particular need for a flow control line.
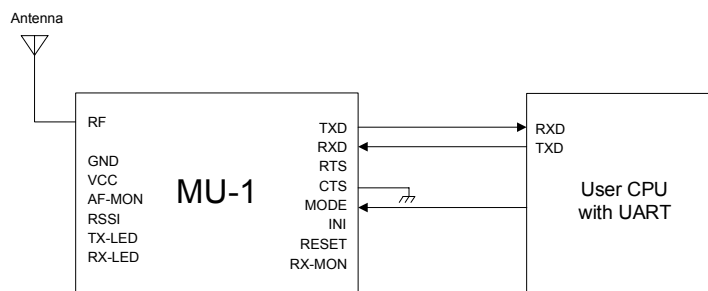
When using hardware flow control
Set the UART of the control CPU to be controlled by hardware flow control.
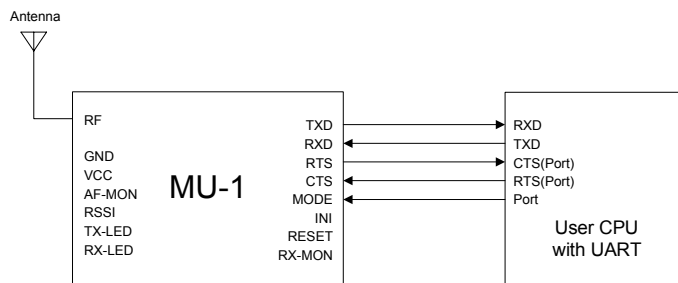
When not using hardware flow control
1. Set the CTS terminal to L level, and open the RTS terminal.
2. Set the UART of the control CPU to no flow control.

■ 5.6.3 How to use the binary mode (when using only the data line of existing equipment)

Caution is necessary when using the MU-1 connected to existing RS232C equipment.
Although RS232C has regulations for its own data format, use of the control line differs depending on the equipment. Equipment that was previously connected with a cable cannot just be connected with the MU-1.
Essentially, the status of the control line can be ignored with only the data line connected, however the data transmission timing and data format of the existing equipment can only be used if it meets the **"Conditions for use of the binary mode"**, explained later.
To check whether these conditions are met, first carry out an investigation using an oscilloscope or the like.

Example of connection
Since the output from existing equipment is normally RS232C, in order to connect to the MU-1, convert the output level with a RS232C transceiver IC. In addition, consider means of enabling the various settings to be made in the command mode.

For example, the following procedure can be used.
1. Provide your circuit board with a socket, and mount the MU-1 after performing the various settings using a dedicated board.
    For example, it is possible to use a RS232C conversion board (MU1-RS2IF) and perform the various settings from a PC.
2. Set the MODE terminal of the MU-1 to L or H with the switch, to switch between the command mode and binary mode.
    Since the various setting commands of the MU-1 are only a few bytes, there is no particular need for a flow control line.
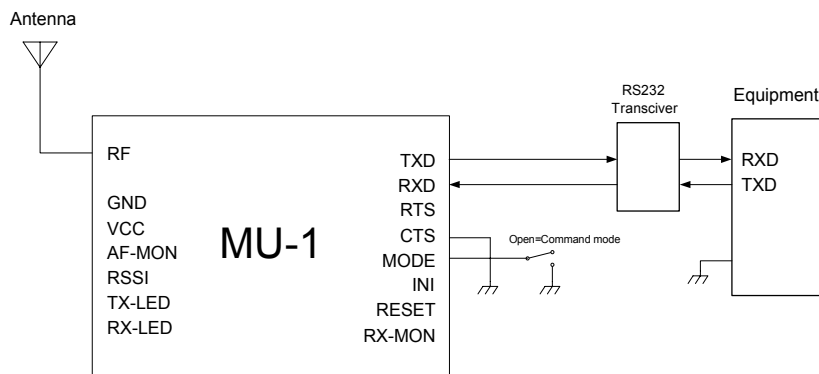
* The MODE terminal is pulled up internally.

■ 5.6.4 Conditions for use of the binary mode

1. Make the size of data sent at one time less than 255 bytes.
2. Data transmission should be timed so that radio transmission of the previously transmitted data is finished completely.

Timing of data transmission
The transmission speed of radio transmission is 9,600 bps, so find the correct timing with the following formula.

Data transmission timing = 21 ms + 1.04 ms × amount of user data + time without input in the binary mode

The start of radio transmission of data follows immediately after the time set with the time without input in the binary mode setting command (@TB) has elapsed.

3. The internal operation of the MU-1 is unreliable for 100 ms after the power is turned on, so data should not be sent during this interval.
4. During input or when data is being sent to the MU-1, do not switch the MODE terminal.

Chapter 6 Commands and Responses

6.1 Format

The following types of MU-1 command and response are possible.
1. Transmit command and response: Command issued to transmit user data, and its associated response.
2. Receive response: Response when the user data is received from the transmitter.
3. Control command and response: Command issued to control the MU-1, and its associated response.
4. Error response: Response when there is an error in the transmit command or control command format.

* In the explanation below, the terminator which is the characters that indicate the delimiter of the command and the response is the symbol 'C$_R$L$_F$'.

        Terminator symbol = 'C$_R$L$_F$': C$_R$ (carriage return: 'C$_R$' = 0Dh) + L$_F$ (line feed: 'L$_F$' = 0Ah)

■ 6.1.1 Transmit command format

Prefix + command name + value + user data + terminator (= 'C$_R$L$_F$')

   Prefix: '@'=40h, a code that indicates the start of the command string.
   Command name: The 2 ASCII characters 'DT'. Specified with upper case or lower case characters.
   Value: Specifies user data size with a hexadecimal number.
   User data: Byte sequence of user data.

Example command
   Command string   Hexadecimal code actually sent to the MU-1
   @DT06abc123C$_R$L$_F$ 40, 44, 48, 30, 36, 61, 62, 63, 31, 32, 33, 0D, 0A

■ 6.1.2 Transmit response format

Prefix + command name + '=' + value + terminator (= 'C$_R$L$_F$')

   Prefix: '*' = 2Ah, a code that indicates the start of the response string.
   Command name: The ASCII characters 'DT'.
   Value: The size of data received with the 'DT' command.

Example command response

   *DT=FFC$_R$L$_F$ Received FFh (255) bytes

■ **6.1.3 Receive response format**

Prefix + response name + '=' + value + user data + terminator (='C$_R$L$_F$')

Prefix:	'*' = 2Ah, a code that indicates the start of the response string.
Response name:	The 2 ASCII characters 'DR'.
Value:	1 byte hexadecimal value to show the size of the user data. Specified by 2 ASCII characters.
User data:	Byte sequence of user data.

Receive response example

Response character string	Hexadecimal code actually returned from the MU-1
*DR=06abc123C$_R$L$_F$	2A, 44, 52, 3D, 30, 36, 61, 62, 63, 31, 32, 33, 0D, 0A

■ **6.1.4 Control command format**

Prefix + command name + value + terminator (= 'C$_R$L$_F$')

Prefix:	'@'=40h, a code that indicates the start of the command string.
Command name:	2 ASCII characters. Specified with upper case or lower case characters.
Value:	Value corresponding to the relevant command.

Example command

Command string	Hexadecimal code actually sent to the MU-1
@CH1FC$_R$L$_F$	40, 43, 48, 31, 46, 0D, 0A

■ **6.1.5 Control response format**

Prefix + command name + '=' + value + terminator (= 'C$_R$L$_F$')

Prefix:	'*' = 2Ah, a code that indicates the start of the response string.
Command name:	2 ASCII characters for the received command.
Value:	Result value corresponding to the relevant command.

Example command response

Response character string	Hexadecimal code actually returned from the MU-1
*CH=1FC$_R$L$_F$	2A, 43, 48, 3D, 31, 46, 0D, 0A

■ **6.1.6 Error response format**

Prefix + response name + '=' + value + terminator (= 'C$_R$L$_F$')

Prefix:	'*' = 2Ah, a code that indicates the start of the response string.
Response name:	The 2 ASCII characters 'ER'.
Value:	Error code. Refer to the error code list.

Example error response

Response character string	Hexadecimal code actually returned from the MU-1
*ER=1DC$_R$L$_F$	2A, 45, 52, 3D, 31, 44, 0D, 0A

6.2 Command Options

By specifying the option '/W' as continuation of a command, command values can be fixed in the EEPROM within the MU-1.
The next time the power is turned on, the contents of the EEPROM are set to the initial values.

The commands that can specify the option '/W' are as follows.
   UI, GI, EI, DI, CH, BR, PB, SB, MD, TC, TB, CT, RM

Example: Fix the Group ID as 55h

   Command to the MU-1:   @GI55/WC$_R$L$_F$

   Response from the MU-1:   *WR=PSC$_R$L$_F$
                                          *GI=55C$_R$L$_F$

Example: Sets the channel to ch10 and fix it.

   Command to the MU-1:   @CH10/WC$_R$L$_F$

   Response from the MU-1:   *WR=PSC$_R$L$_F$
                                          *CH=10C$_R$L$_F$

⚠ **Caution**	The command parameter is applied immediately after the command to change it is issued. In particular, note that if the UART related parameters are changed, communication will not be possible unless the UART parameters on the control side are changed.

6.3 Command and Response Table

■ 6.3.1 Transmit command and response

Command type	Function	Command	Response
Transmit command	Transmits data	@DT XXxx…xx	*DT=XX

■ 6.3.2 Receive response

Response type	Function	-	Response
Receive response	Response when data is received	-	*DR=XXxx...xx

■ 6.3.3 Control commands and responses

Control command type	Function	Command	Response
Radio link related setting and acquisition commands	Sets the User ID	@UI XXXX,XXXX	*UI=XXXX
	Sets the Group ID	@GI XX	*GI=XX
	Sets the Equipment ID	@EI XX	*EI=XX
	Sets the Destination ID	@DI XX	*DI=XX
	Sets the channel to use	@CH XX	*CH=XX
	Acquires the value for the RSSI level	@RS	*RS=XX
	Acquires the RF received signal level reference value	@SG XX	*SG=XX
UART parameter setting commands	Sets the UART baud rate	@BR XX	*BR=XX
	Sets the UART parity	@PB XX	*PB=XX
	Sets the UART stop bit	@SB XX	*SB=XX
Operation setting and information acquisition commands	Sets the operation mode	@MD XX	*MD=XX
	Sets the command mode input waiting time	@TC XX	*TC=XX
	Sets the time without input in the binary mode	@TB XX	*TB=XX
	Link data continuous transmission	@CT XX	*CT=XX
	Sets the response display mode	@RM XX	*RM=XX
	Acquires the ROM version	@VR	*VR=XXxx...xx

XXX, XXXX indicates a value. xxx indicates a byte sequence or character string.

■ 6.3.4 Error response

Error responses have the format '*ER=XX'. Refer to "Command and Response Details".

6.4 Command and Response Details

■ 6.4.1 Transmit command and response

@DT   Transmit data
   '@' + 'DT' + data size + data + C_RL_F
Data size is specified by 2 hexadecimal ASCII characters.
The maximum data size that can be sent at one time is 255 bytes.
When the MU-1 receives the '@DT' command, it performs data transmission and returns a response at the same time.

   Format   @DTXXxxxx….xxxxC_RL_F
                        XX :   Shows the data size in hexadecimal
                        xxx…xxx :   Data   max. 255 bytes

Example: Transmits 20-byte data (14h) '012345ABCD@$%CIRCUIT'.
   Command to the MU-1:   @DT14012345ABCD@$%CIRCUIT$C_RL_F$
   Response from the MU-1:   *DT=14C_RL_F

■ 6.4.2 Receive response

*DR   Data received
   When the MU-1 receives user data normally, the received data is output following the '*DR' response.

   Example: Receives 20-byte user data (14h) '012345ABCD@$%CIRCUIT'
   Receive response from the MU-1:   *DR=14012345ABCD@$%CIRCUIT$C_RL_F$

■ 6.4.3 Control commands and control responses

⚠ **Caution**	The command parameter is applied immediately after the command to change it is issued. In particular, note that if the UART related parameters are changed, communication will not be possible unless the UART parameters on the control side are changed.

@BR   UART baud rate
   Sets the UART baud rate. The change of setting is applied immediately after the response to the command is returned. Change the baud rate on the control side immediately.
   Default: 19
   Value: 12 = 1,200 bps   24 = 2,400 bps   48 = 4,800 bps   96 = 9,600 bps
                       19 = 19,200 bps   38 = 38,400 bps   57 = 57,600 bps
   Example: Change to 57,600 bps
     Command to the MU-1:   @BR57C_RL_F Response from the MU-1:   *BR=57C_RL_F

@CH　　　Frequency channel to use

Sets the channel to be used. Specify the channel following '@CH' with 2 ASCII (hexadecimal) characters.

　　Default:　07h
　　Value:　07h - 2Eh (hexadecimal value that indicates channels 7 to 46)

　　Example: Change the channel to 31
　　　　Command to the MU-1:　　　　@CH1FC$_{RLF}$　　　　　　Response from the MU-1:　*CH=1FC$_{RLF}$

@CT　　　Link data continuous transmission

Continuously transmits link test data. When continuous transmission is enabled, the C$_{RLF}$ code is transmitted repeatedly from the MU-1. If there is any input data during transmission, the data is transmitted.

　　Default:　'OF'
　　Value:　　　　'ON':　Continuous transmission on　　　　'OF':　Continuous transmission off

　　Example 1: Set to continuous transmission on
　　　　Command to the MU-1:　　　　@CTONC$_{RLF}$　　　　　　Response from the MU-1:　*CT=ONC$_{RLF}$
　　Example 2: Set to continuous transmission off
　　　　Command to the MU-1:　　　　@CTOFCRLF　　　　　　Response from the MU-1:　*CT=OFCRLF

@DI　　　Destination ID setting

Sets the destination (target station). Refer also to the explanation of User ID and Group ID.
If 00 is specified as the Destination ID, all equipment within the same group will receive the data at the same time (broadcast function). If FFh is set, the data is sent but no station will receive it.

　　Default:　01h
　　Value: 00h to FFh (00h and FFh are special operations)

　　Example: Change the Destination ID to 25h
　　　　Command to the MU-1:　　　　@DI25C$_{RLF}$　　　　　　Response from the MU-1:　　*DI=25C$_{RLF}$

@EI　　　Equipment ID setting

Sets the Equipment ID. One group can contain 254 units. Refer also to the explanation of User ID and Group ID.
The Equipment ID 00h is used for the broadcast function, and there is no reason for setting it.
If the Equipment ID FFh is specified, data will not be received. In this case, if the '@RS' command is used, only RSSI level data is output.

　　Default:　01h
　　Value:　01h to FFh (FFh is a special operation)

　　Example: Change the Equipment ID to 34h
　　　　Command to the MU-1:　　　　@EI34C$_{RLF}$　　　　　　Response from the MU-1:　*EI=34C$_{RLF}$

@GI   Group ID setting
Sets the Group ID. Refer also to the explanation of the User ID.
There are 256 Group IDs. Maintain these IDs for use as identification numbers when building other user systems.

   Default: 00h
   Value: 00h to FFh

   Example: Change the Group ID to 34h
      Command to the MU-1:   @GI34C$_R$L$_F$ Response from the MU-1:   *GI=34C$_R$L$_F$

@MD   MU-1 operation mode register setting
Sets the MU-1 operation mode register. The mode is determined in accordance with the status of the MODE terminal.
For details, refer to the item "Modes". No commands can be used except in the command mode (CD).
   Default: CD
   Value: CD: Command mode   TX: Text mode   BI: Binary mode

   Example 1:   Change to the text mode
      Command to the MU-1:   @MDTXC$_R$L$_F$ Response from the MU-1:   *MD=TXC$_R$L$_F$
   Example 2:   Change to the binary mode
      Command to the MU-1:   @MDBIC$_R$L$_F$ Response from the MU-1:   *MD=BIC$_R$L$_F$

@PB   UART parity
Sets the UART parity bit of the MU-1. The change of setting is applied immediately after the response to the command is returned. Change the parity on the control side immediately.
   Default: NO
   Value: NO = None   EV = Even   OD = Odd
   Example: Change to even parity
      Command to the MU-1:   @PBEVC$_R$L$_F$ Response from the MU-1:   *PB=EVC$_R$L$_F$

@RM   Response display mode
Sets the method of displaying the content of error responses to either code or text.
Text display is the mode for connecting to a PC with a RS232C conversion board in order to check the content of responses.
Normally the code display mode should be used.

   Default: CD
   Value: CD: Code display mode   TX: Code or text display mode
   Example: Change the response display method to code display
      Command to the MU-1:   @RMCDC$_R$L$_F$ Response from the MU-1:   *RM=CDC$_R$L$_F$

@RS   RSSI level value acquisition
Acquires the received signal level of the currently set channel. The RSSI level value is the 8-bit AD conversion value of the CPU.

   Example: Acquire the current channel RSSI level

      Command to the MU-1:   @RSC$_R$L$_F$
   Response from the MU-1:   *RS=81C$_R$L$_F$ (RSSI level value: 00h to FFh)

@SB   UART stop bit setting
Sets the UART stop bit of the MU-1. The change of setting is applied immediately after the response to the command is returned. Change the stop bit on the control side immediately.
   Default: 01
   Value: 01 = Stop bit 1   02 = Stop bit 2
   Example: Change to Stop bit 1
      Command to the MU-1:   @SB01C$_R$L$_F$ Response from the MU-1:   *SB=01C$_R$L$_F$

@SG   RF received signal level reference value acquisition

Acquires the reference value in order to determine the absolute level of the RF received signal.
When each MU-1 is shipped from the factory, the receive level at -100 dBm as measured with the SSG (standard signal generator) as the standard, and the gradient (increase in 10 dB steps) is written in the EEPROM.
Using this value, the absolute level of the received signal level of the receiving channel can be determined.
　Value:
　13 = -130 dBm, 12 = -120 dBm, 11 = -110 dBm, 10 = -100 dBm, 90 = -90 dBm, 80 = -80 dBm, 70 = -70 dBm

If 00 is specified, the gradient value when the reference is set at -100 dBm can be acquired.
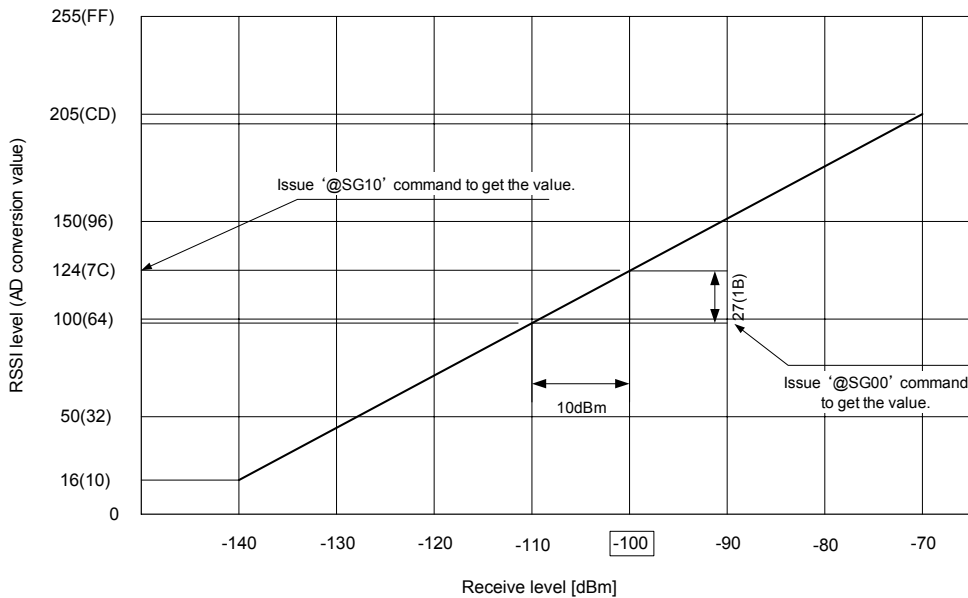
Example: Obtain the received signal level at -100 dBm.
　Command to the MU-1:　　　@SG10C$_R$L$_F$　　　　　Response from the MU-1:　*SG=7CC$_R$L$_F$

Example: Obtain the gradient of the MU-1 received signal level characteristics with the reference set at -100 dBm.
　Command to the MU-1:　　　@SG00C$_R$L$_F$　　　　　Response from the MU-1:　*SG=1BC$_R$L$_F$

@TB   Time without input in the binary mode setting

In the binary mode, if the status where no UART data is input continues beyond the set time, transmission of data in the buffer starts automatically.
Calculate the setting value with 32 ms per 1 count.

　Default:　10h　(16 × 32 = 0.512 s)
　Value:　　01h to FFh:　1 count = 32 ms
　Example: Set the time to 20h (1.02 s)
　　Command to the MU-1:　　　@TB20C$_R$L$_F$　　　　　Response from the MU-1:　*TB=20C$_R$L$_F$

@TC　　Command mode input waiting time

If command input is not completed within the time set, the character string input so far is cleared and the unit returns to the input standby status.
Calculate the setting value with 1.024 s per 1 count.

　　Default:　　　00h (No limit for input time)
　　Value:　　　 00h to FFh
　　Example: Set waiting time to 0Ah (10 × 1.024 = 10.24 s)
　　　　Command to the MU-1:　　　　@TC0AC$_{R}$L$_{F}$　　　　　　　Response from the MU-1:　　*TC=0AC$_{R}$L$_{F}$

　* This command is provided to support software such as HyperTerminal for sending character data with key input.

@UI　　　**User ID setting**

User IDs are IDs (about 65,000) that are meant to prevent data interference with other systems within a given area, and if all the equipment within the same user system does not have the same ID, communication cannot be established. The Link ID derives from the Group ID, Equipment ID, and Destination ID. The User ID is not necessarily unique to each user, and there may be duplicates. In other words, the User ID does not guarantee the security of data.
All MU-1 units have a default User ID of 0000h, and they can be used with this value, but to avoid data collision with other users in the same area, we recommend that you set a User ID other than 0000h for actual operations with the MU-1.
If you require us to issue a User ID, we will provide you one, with a password. Please contact the distributor or Circuit Design, Inc. Please ensure that you do not lose your User ID and password.

　　Default:　0000h
　　Value:　　0000h to FFFEh (0000h is the ID for testing, and FFFFh cannot be used)

　　Example:　　　　　　　Set the User ID to 0000h with the password 0B27h provided.
　　　　Command to the MU-1:　　　　@UI 0000,0B27C$_{R}$L$_{F}$
　　　　Response from the MU-1:　　　*GI=0000C$_{R}$L$_{F}$

　* For ordinary applications, fix the UI, GI, and EI in the EEPROM with the command /W option.
　* Please contact the distributor or Circuit Design, Inc. if you require multiple User IDs.

@VR　　Program version

Obtains the program version of the MU-1.
　　Example:
　　　　Command to the MU-1:　　　　@VRC$_{R}$L$_{F}$
　　　　Response from the MU-1:　　　*VR=11 Ver1.1 2003/08/29 15:00C$_{R}$L$_{F}$

■ 6.4.4 Error responses

If there is an error in the format of the transmit command or control command issued, an error code of the type shown below is sent in response.
These error codes are required during product development, but you should ensure that errors do not occur with your product.

It is possible to change the display format by issuing the response display mode setting command '@RM=TX' or '@RM=CD'. In the default settings, only error codes are displayed.

Example: Error response when the '@BR' command is issued
    1. When '@RM=CD' is set
        *ER=0A$_{C_RL_F}$
    2. When '@RM=TX' is set
        *ER=0A: BR command format error $_{C_RL_F}$

Code	Description	Meaning
01	Issued command is not found	The issued command does not exist
02	Channel data error	The specified channel is outside the range
03	CH command error	Use a 2-digit Hex character for the 'CH' command
04	CH command format error	The 'CH' command format is wrong
05	DT command error	Use a 2-digit Hex character for the 'DT' command
06	DT command format error	The 'DT' command format is wrong. Check the data size.
07	-	
08	RS command format error	The 'RS' command format is wrong
09	RM command format error	The 'RM' command format is wrong
0A	BR command format error	The 'BR' command format is wrong
0B	-	
0C	MD command format error	The 'MD' command format is wrong
0D	DI command error	Use a 4-digit Hex character for the 'DI' command
0E	DI command format error	The 'DI' command format is wrong
0F	EI command error	Use a 4-digit Hex character for the 'EI' command
10	EI command format error	The 'EI' command format is wrong
11	TC command format error	The 'TC' command format is wrong
12	TB command format error	The 'TB' command format is wrong
13	Command input time exceeds limit	The time limit for inputting the command was exceeded
14	-	
15	CT command format error	The 'CT' command format is wrong
16	-	
17	UI command error	Use a 4-digit Hex character for the 'UI' command
18	UI command format error	The 'UI' command format is wrong
19	-	
1A	PB command format error	The 'PB' command format is wrong
1B	SB command format error	The 'SB' command format is wrong
1C	-	
1D	SG command format error	The 'SG' command format is wrong

Chapter 7 Miscellaneous

7.1 Timing Diagrams

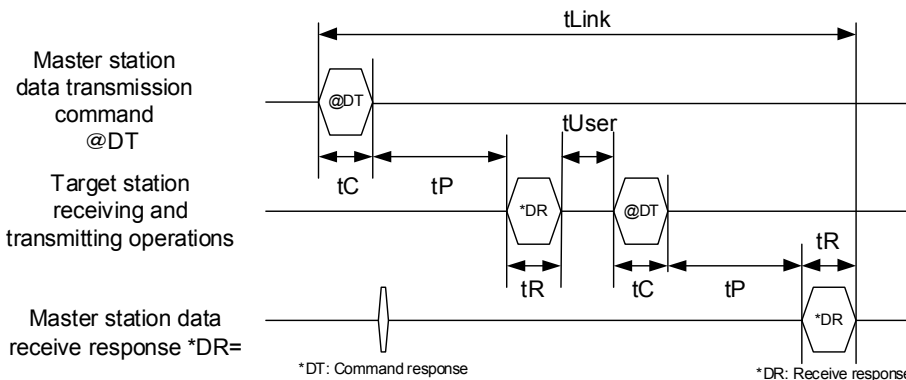◆ Period after power on when commands must not be issued

Power ON

Power supply (VCC)

MU-1 operation

Commands can be issued

100 ms
Period when commands must not be issued
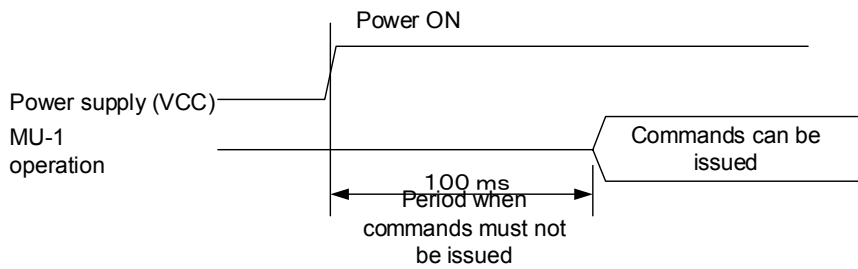
◆ Transmission time (1 frame)
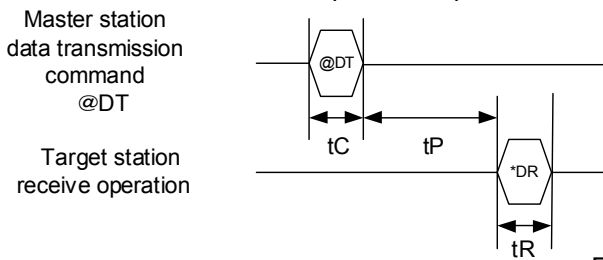
Master station data transmission command @DT

@DT

tC   tP

Target station receive operation

*DR

tR

Command time $tC = (n + 7) \times 10/br$

Radio transmission time $tP = (n \times 1.04) + 23$

Response time $tR = (n + 8) \times 10/br$

* Units: ms, n = Amount of transmission data (within 255 bytes), br = UART bit rate

◆ Time to establish link (1 frame)

tLink

Master station data transmission command @DT

@DT

tC   tP

tUser

Target station receiving and transmitting operations

*DR   @DT

tR   tC   tP

tR

Master station data receive response *DR=

*DR

*DT: Command response

*DR: Receive response

Command time $tC = (n + 7) \times 10/br$

Radio transmission time $tP = (n \times 1.04) + 23$

Response time $tR = (n + 8) \times 10/br$

tUser = User program processing time

tLink = Time to establish link

* Units: ms, n = Amount of transmission data (within 255 bytes), br = UART bit rate

* Reference value with 20-byte link data: tLink = 107 ms   Conditions: 57,600bps, no tUser

◆ General command and response timing
  (Excluding @CH, @RS commands)

Issue command

Response

0.32ms   tR

tC
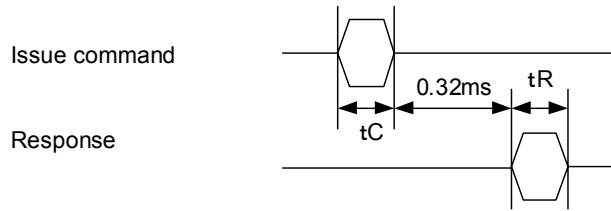
$$tC = A \times 10/br \qquad tR = B \times 10/br$$

A = Command length
A=7: GI,EI,DI,CH,SG,BR,PB,SB,MD,TC,TB,CT,RM
A=5: RS,VR
A=14: UI

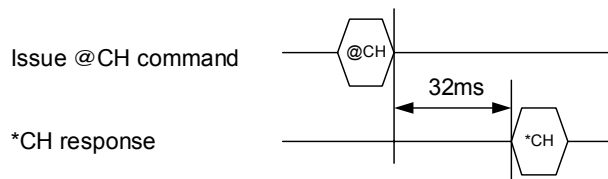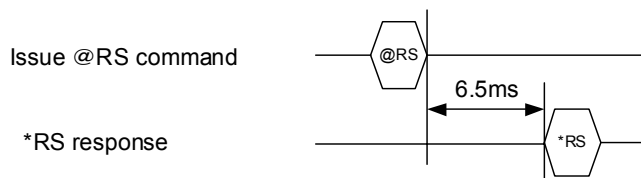B = Response length
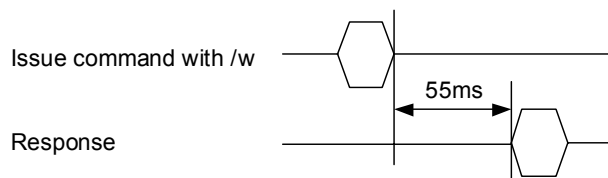B=8: GI,EI,DI,CH,RS,SG,BR,PB,SB,MD,TC,TB,CT,RM
B=10: UI

◆ CH command and response timing

Issue @CH command   @CH

32ms

*CH response   *CH

◆RS command and response timing

Issue @RS command   @RS

6.5ms

*RS response   *RS

◆ Command and response timing when /w option is specified

Issue command with /w

55ms

Response

* 87 ms with @CH/w

7.2 Method of Evaluation Using HyperTerminal

* We recommend that you use the dedicated *MU-1 Evaluation Software Program* for performing operational checks and evaluation of the MU-1.

You can also perform a simple operational check using the Windows accessory HyperTerminal. The following is an explanation of how to use HyperTerminal, and cautions when using the program. Please read the detailed explanation of the commands before starting the evaluation. When performing evaluation using a computer, mount the MU-1 on a RS232C conversion board.

■ 7.2.1 Preparing the MU-1

Before starting the evaluation, turn on the power while pressing the RESET switch of the RS232C conversion board, and turn on the power again to initialize the content of the EEPROM (non-volatile memory) inside the MU-1. The initial values of the parameters are as follows.

Initial values for link related parameters
  User ID = 0000h Group ID = 00h
  Equipment ID = 01h Destination ID = 01
  Channel to use CH = Lowest channel number
**Initial values for RS232C related parameters**
  Baud rate: 19,200 bps, Data bits: 8 bits, Parity: none,
  Stop bit: 1, Flow control: RTS, CTS hardware control

* Initialization using the RESET switch initializes all of the MU-1 parameters, so do not press it for any other reason than initialization.

■ 7.2.2 Evaluation using HyperTerminal

Start up HyperTerminal, then set the communication parameters using the example at right for reference. Refer to the Cautions for important information.
Issue the various commands from the keyboard.
Refer to the section on modes for evaluating the different modes.

■ 7.2.3 HyperTerminal settings
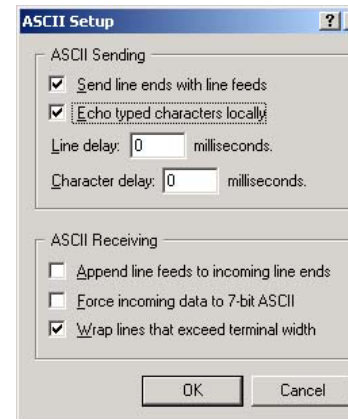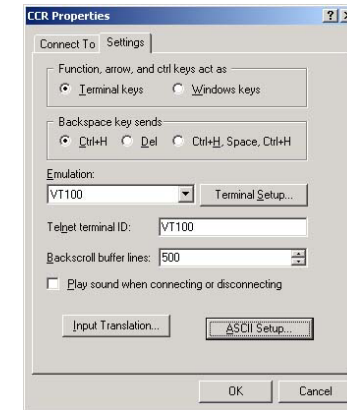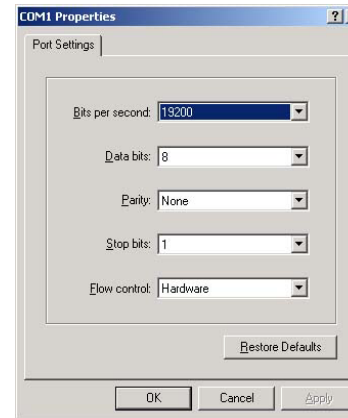
■ 7.2.4
Cautions when using HyperTerminal

1. 'C$_R$L$_F$' in the detailed explanation of commands means the "Enter" key on the computer keyboard. When testing the commands with HyperTerminal or the like, press the "Enter" key for CRLF. However, the "Enter" key on the number keypad outputs 'C$_R$' in HyperTerminal, so it should not be used.

2. With HyperTerminal, pressing a key outputs the corresponding code, so the "Backspace" key and "Delete" key should not be pressed.

3. With HyperTerminal, the DTR line is always fixed at High Level and cannot be controlled.

Chapter 8 Regulatory Compliance

8.1 Regulatory Compliance of the MU-1

■ 8.1.1 Regulatory compliance of the MU-1

The MU-1 is made for embedding in other equipment.
(Products with the MU-1 embedded are henceforward referred to as the final product.)
The European regulations applying to the MU-1 is the R&TTE Directive 1999/5/EC.
MU-1 meets the following requirements of the R&TTE Directive.

R&TTE Directive article	Test category	Harmonized standard
Articles 3.1 (a)	Protection of health and safety	EN60950, EN 50371
Articles 3.1 (b)	EMC	EN 301 489-1/-3
Articles 3.2	Effective use of the spectrum	EN 300 220-3

The conformity assessment for the MU-1 was completed in accordance with the R&TTE Directive Annex III procedures, and the EC Declaration of Conformity is attached to this manual. The MU-1 has received the CE mark.

■ 8.1.2 Cautions regarding regulatory compliance when embedding the MU-1

1. Duty cycle and frequency channel
The transmitting time and downtime of the MU-1, and selection of the frequency channel are controlled by the final product in which the MU-1 is embedded. The radio component of the final product must be designed so that the duty cycle, channel spacing and frequency conform to the radio regulations of the countries where it is to be used. The MU-1 is designed to be operated in **e** and **e2** frequency band for Non-Specific Short Range Devices operating in the 433.050 to 434.790 MHz band shown in Table 1 below. Specifically, the MU-1 is canalized in 25 KHz steps and has channels 0 to 63 in the 433.050 to 434.790 MHz band (Refer to 2.3 "Usable Channels"). The nominal RF output of the MU-1 is 10 mW.

Caution: If the MU-1 is used at 433.050 to 434.040 MHz with a duty cycle higher than 10%, the manufacturer of the final product must notify the radio regulatory authority in the countries where it is to be sold.

	Frequency band	Power	Channel spacing	Duty cycle (%)*
e	433.050 - 434.790 MHz	10 mW e.r.p.	No channel spacing	Below 10%
e1	433.050 - 434.790 MHz	1 mW e.r.p. -13 dBm/10 kHz for wide band channels	No channel spacing	No duty cycle restriction
e2	434.040 - 434.790 MHz	10 mW e.r.p.	Up to 25 kHz	No duty cycle restriction

* Duty cycle is the longest time when transmission is "on" in a single carrier frequency within one hour, expressed as a percentage.

Table 1

The frequency band **e** of Annex 1 in the above table has been harmonized.

Radio equipment using these harmonized frequencies with technical characteristics in accordance with the R&TTE Directive is classified as Class 1 radio equipment. Class 1 radio equipment can be placed on the market and put into service without restrictions in all EC Member States.

Radio equipment not in the above mentioned harmonized frequencies with different technical characteristics is classified as Class 2 radio equipment for which some Member States apply restrictions on placing on the market and in use.

Any parties putting Class 2 radio equipment on the market must notify the relevant national spectrum management authority of their intention, and the radio equipment must be given a Class Identifier (alert symbol).

Specifically, final products that incorporate the MU-1 are classified as Class 1 if the final product maintains the MU-1 within the 433.050 to 434.790 MHz frequency band, with a duty cycle of less than 10%. Otherwise, for example, if a final product incorporating the MU-1 is used at more than 10% duty cycle, it is classified as Class 2 and requires notification and an alert symbol.

Use of the MU-1 with duty cycles less than 10%

① When using the MU-1 in duty cycles of less than 10%, all channels (0 to 63) can be used.

② When using the MU-1 in duty cycles of more than 10% (for continuous transmission and so on), only channels 34 to 63 should be used. In this case, the final product is classified as Class 2 radio equipment.

The following table shows the programmable frequency channel range of the MU-1 and its relationship with the range specified in ERC/REC 70-03 Annex 1.

ERC/REC 70-03 Annex 1		MU-1		
	Frequency Band	Usable channels	Frequency alignment range	Spacing
e	433.050 to 434.790 MHz	0 to 63	433.200 to 434.755 MHz	25 KHz
e2	434.040 to 434.790 MHz	34 to 63	434.050 to 434.755 MHz	25 KHz

Remarks: This information is correct as of May 2004.

2. Antenna

The radio and EMC parameters of the MU-1 have undergone conformity evaluation with the lead antenna model ANT-LEA-01 provided as a standard accessory. Other antennas cannot be used. If another antenna is used, the results of the radio conformity assessment obtained by the MU-1 cannot be used for the conformity assessment of the final product.

3. Supply voltage

The MU-1 should be used within the specified 3V to 5V voltage span.

4. Enclosure

The MU-1 is made for embedding in another final product. For this reason, there are some parts of the final product on which the MU-1 depends for regulatory compliance regarding EMC and safety.

The MU-1 is mounted on the circuit board of the final product, and must be contained inside the case of the final product. Embed the MU-1 in the final product so that its surfaces are not in contact with the outside.

5. Documentation

In the documentation for the conformity assessment of the final product, state clearly that the MU-1 is embedded in the system. (The MU-1 has received the CE mark.)

8.2 Conformity Assessment of Products Embedded with the MU-1

The following is a supplementary explanation of conformity assessments for final products embedded with radio modules such as the MU-1, that have passed conformity assessments in accordance with the R&TTE Directive.

■ 8.2.1 Conformity assessments of final products

The procedures for conformity assessment in accordance with the R&TTE Directive are the responsibility of the manufacturer of the final product. With final products with embedded radio modules, the person who embeds the module in the system becomes the manufacturer of the final product, and it is their responsibility to certify that the requirements of the R&TTE Directive are met.

■ 8.2.2 Exemption from conformity assessment

However, if radio modules that meet the requirements of the R&TTE Directive and that have passed the conformity assessment are embedded in a final product that follows the cautions concerning embedded radio modules, they are exempted from the conformity assessment for R&TTE Directive Article 3.2 (efficient use of the radio spectrum). For details, refer to the following Guidance and ETSI Technical Report from the R&TTE Compliance Association, and check whether your case applies.

Organization	R&TTE Compliance Association	Document No.	TGN 01 Rev 3
Document title	Technical Guidance Note on Requirement for a Final Product that Integrates an R&TTE Directive Assessed Module		
URL /Download	You can download the guidance from the download area of R&TTE Compliance association. http://www.rtteca.com/		

Organization	ETSI (Technical report)	Document No	ETSI TR102 070-2
Document title	Electromagnetic compatibility and Radio spectrum Matters (ERM); Guide to the application of harmonized standards to multi-radio and combined radio and non-radio equipment; Part 2: Effective use of radio frequency spectrum		
URL /Download	You can download the guide from the ETSI web site by entering TR102 070-2 in the search engine. Before downloading, you will be requested to register. http://www.etsi.org/		

■ 8.2.3 Conformity assessment procedures for final products exempted from R&TTE Directive Article 3.2 assessment

In every case, the manufacturer of a final product must follow the procedures for conformity assessment of the final product with the requirements of R&TTE Directive Articles 3.1 (a) and (b), for safety and EMC.
The conformity assessment for Article 3.2 is carried out in accordance with the following.

1. Attach the EN300-220-3 test report of the assessed radio module and the EC Declaration of Conformity to the conformity assessment of the final product. (The Declaration of Conformity is attached to the manual.)
2. Specify on the conformity assessment of the end product that the assessed radio module was embedded in the system without any changes, in accordance with the installation directions of the manufacturer.

■ 8.2.4 Notification of the final product

The notification required by R&TTE Directive Article 6 (4) is not necessary if the final product uses the frequencies and technical characteristics harmonized throughout the Community and is classified as Class 1 radio equipment.
If the final product uses frequency bands and has technical characteristics that are not harmonized throughout the Community and is classified as Class 2 equipment, it is the responsibility of the manufacturer of the final product to notify the relevant national spectrum management authority of the intention to place the final product on the market.

■ 8.2.5 CE marking

It is necessary to attach the CE mark to the final product to indicate that it conforms with all the directives that apply to the final product.
If the final product uses frequency bands and has technical characteristics that are not harmonized throughout the Community and is classified as Class 2 equipment, it must be given a Class Identifier (alert symbol) in addition to the CE mark.

■ 8.2.6 Exemption clause

Circuit Design, Inc. does not guarantee the accuracy of the information above.
Directives, technical standards, principles of operation and the like are interpreted differently by the authorities in each country. The directives of the EU and of each country also differ. In case of doubt or uncertainty, we recommend that you check with the authorities or official certification organizations of the relevant countries.

8.3 Declaration of Conformity

DECLARATION OF CONFORMITY
Directive 99/5/EC (R&TTED)

Manufacturer or
Authorized representative: Circuit Design, Inc.

Address: 7557-1, Hotaka, Hotaka-machi, Minamiazumi, Nagano
                                399-8303 Japan

We declare on our sole responsibility, that the following product:

Kind of equipment: Radio modem

Type-designation: MU-1 434MHz

is in compliance with the essential requirements of §3 of the R&TTED.

- Health and safety requirements pursuant to §3(1)a:
   Applied Standard(s) or other means of providing conformity:

EN 50371 : 2002
EN 60950 : 2000

- Protection requirements concerning EMC §3(1)b:
   Applied Standard(s) or other means of providing conformity:

EN 301 489-3 V1.4.1 (08.2002)

- Measures for the efficient use of the radio frequency spectrum §3(2)
   Applied Standard(s) or other means of providing conformity:

EN 300 220-3 V1.1.1 (09.2000)

Hotaka, Japan   April 20, 2004
      place and date of issue   Manufacturer/Authorized representative
                                                             name and signature

Cautions

- As the radio module communicates using electronic radio waves, there are cases where transmission may be temporarily cut off due to the influence of the surrounding environment or method of use. The manufacturer is exempt from all responsibility relating to resulting harm to personnel or equipment and other secondary damage.
- Do not use the equipment within the vicinity of devices that may malfunction as a result of electronic radio waves from the radio module.
- The manufacturer is exempt from all responsibility relating to secondary damage resulting from the operation, performance and reliability of equipment connected to the radio module.
- Communication performance will be affected by the surrounding environment, so communication tests should be carried out before actual use.
- Ensure that the power supply for the radio module is within the specified rating. Short circuits and reverse connections may result in overheating and damage, and must be avoided at all costs.
- Ensure that the power supply has been switched off before attempting any wiring work.
- The case is connected to the GND terminal of the internal circuit, so do not make contact between the '+' side of the power supply terminal and the case.
- When batteries are used as the power source, avoid short circuits, recharging, dismantling, and pressure. Failure to observe this caution may result in the outbreak of fire, overheating and damage to the equipment. Remove the batteries when the equipment is not to be used for a long period of time. Failure to observe this caution may result in battery leaks and damage to the equipment.
- Do not use this equipment in vehicles with the windows closed, in locations where it is subject to direct sunlight, or in locations with extremely high humidity.
- The radio module is neither waterproof nor splash proof. Ensure that it is not splashed with dirt or water. Do not use the equipment if water or other foreign matter has entered the case.
- Do not drop the radio module or otherwise subject it to strong shocks.
- Do not subject the equipment to condensation (including moving it from cold locations to locations with a significant increase in temperature.)
- Do not use the equipment in locations where it is likely to be affected by acid, alkalis, organic agents or corrosive gas.
- Do not bend or break the antenna. Metallic objects placed in the vicinity of the antenna will have a great effect on communication performance. As far as possible, ensure that the equipment is placed well away from metallic objects.
- The GND for the radio module will also affect communication performance. If possible, ensure that the case GND and the circuit GND are connected to a large GND pattern.

Warnings

- Do not take apart or modify the equipment.
- Do not remove the product label (the label attached to the upper surface of the module.) Using a module from which the label has been removed is prohibited.