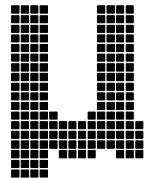Embedded low power radio modem

# MU-1-R 434MHz

## Operation Guide

**Version 1.4 (Sep. 2015)**

**The MU-1-R is an RoHS compliant radio modem. "-R" is added as an identification to RoHS compliant products. In this Operation Guide, please read "MU-1" as "MU-1-R"**

**CIRCUIT DESIGN, INC.,**

7557-1 Hotaka, Azumino
Nagano 399-8303, JAPAN
Tel: +81+(0)263-82-1024
Fax: +81+(0)263-82-1016

E-mail: info@circuitdesign.jp
Web site: http://www.cdt21.com

# 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. Using the relay function it is also possible to gather data from and control equipment in remote locations.

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**

**It is not possible simply to replace communication using existing RS232C system equipment connected with a cable, with MU1 wireless communication. 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.
➢    Long distance communication is possible using a maximum of 10 relay stations.
➢    User data can be output at each relay station.
➢    It is possible to assess locally the status of radio waves and field noise at the target station and source station.
➢    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

## 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
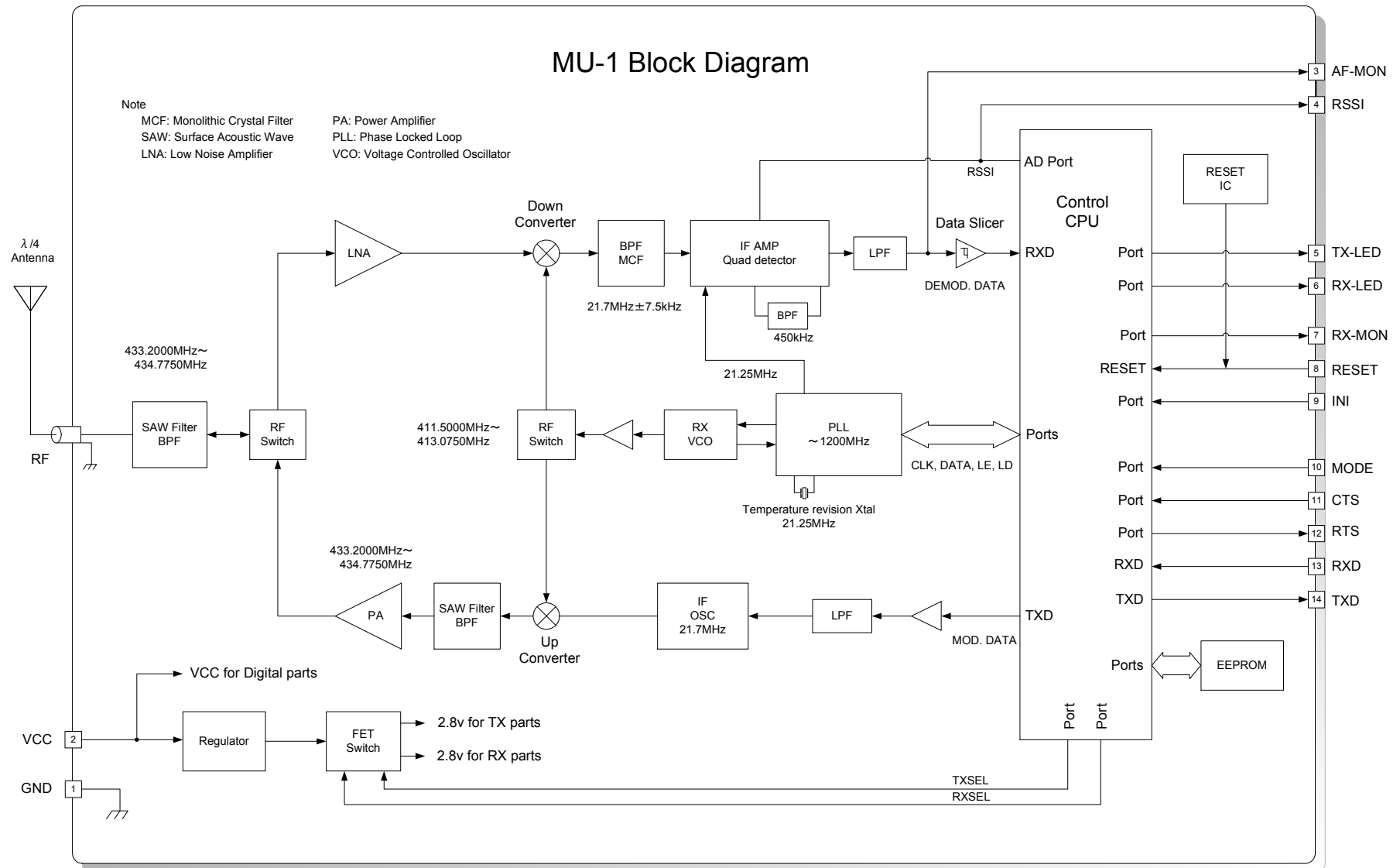
## 1.3 Example of the Control Method

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: Controlling the MU-1 with 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.
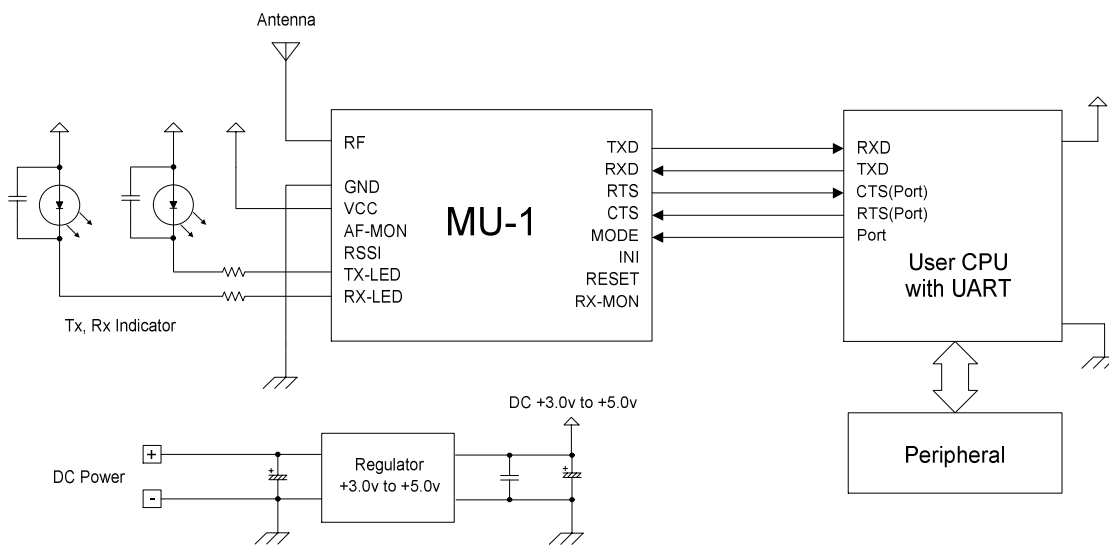


■ **1.3.2 Example 2: Controlling the MU-1 via RS232C**

1. Using the RS232 port of your computer, you can develop a new program for OSs 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.
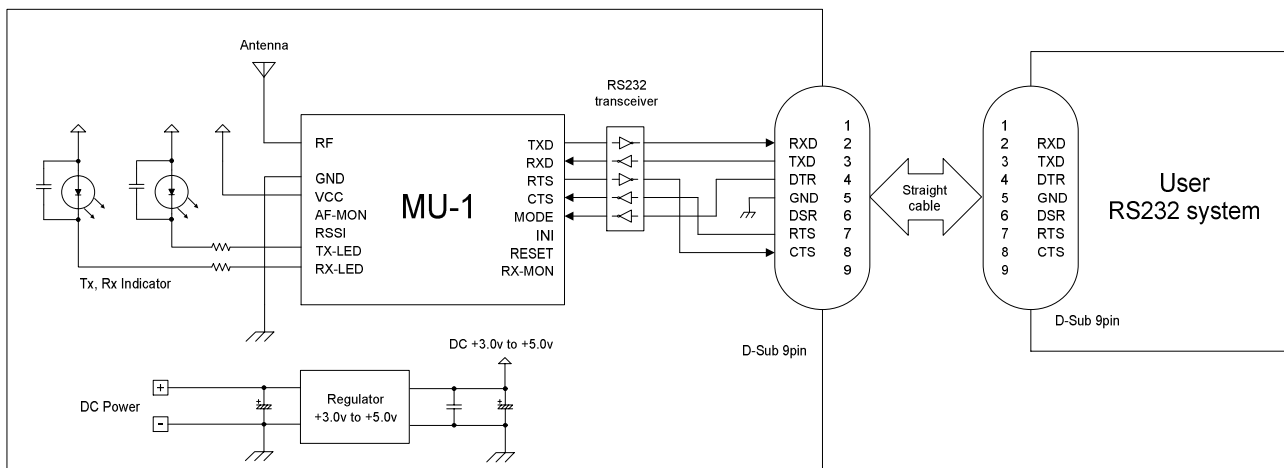
# Chapter 2 Specifications and Diagram

## 2.1 Main Specifications

### ■ 2.1.1 General specifications

Temperature conditions: +25ºC ± 5ºC

| Item | Specification | Remarks |
|---|---|---|
| Compatible standards | R&TTE Directive EN1999/5/EC | CE mark acquired |
| Emission class | F1D | |
| Antenna power | Within 8 +20% -50% | Contact (50 Ω) |
| Frequency stability | Within ± 4 ppm | -10ºC to +55ºC |
| Antenna | 1/4λ wire antenna | Gain of 2.14 dBi or less |
| Communication method | Half-duplex or one-way | |
| Modulation system | Binary FSK | |
| Oscillation system | PLL synthesizer system | |
| Radio communication speed | 9,600 bps | |
| Frequency range | 433.2000 to 434.7750 MHz | |
| Number of channels | 64 | Channel span 25 kHz |
| Receiver spurious radiation | -60 dBm or less | |
| Receiver sensitivity | -108 dBm | Packet error rate 0.1%<br>(255 bytes/1 packet) |
| Operating temperature | -20ºC to +60ºC | The range varies with the temperature conditions. |
| Working humidity | 80% RH or less | |
| Storage temperature | -25ºC to +70ºC | |
| Storage humidity | 80% RH or less | |
| Operating voltage | 3.0 V to 5.0 V | Absolute maximum rated voltage 5.5 v |
| Consumption current | Transmitting: 46 mA<br>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 mm × 30 mm × 9 mm<br>(W × D × H) | Not including the antenna.<br>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, 25ºC
* Range: About 600 m / Conditions: one-way communication, no error correction, 25ºC, 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
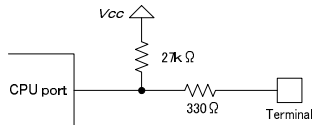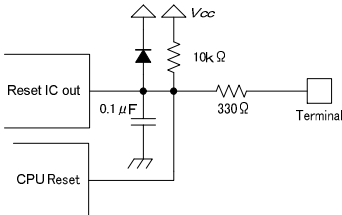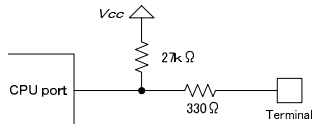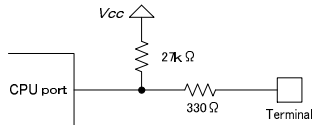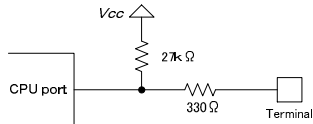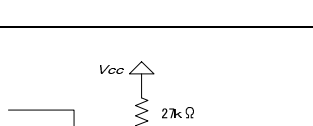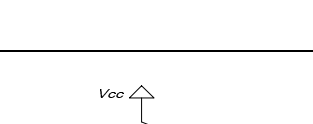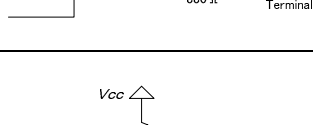
### ■ 2.1.2 UART interface specifications

| | |
|---|---|
| Communication method | Serial communication (RS232C format) |
| Synchronization | Start-stop (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, stop bits 1 or 2 |

## 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.

| Terminal 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: | @CH 1F CRLF |
| Response from the MU-1: | *CH = 1F CRLF |

\* ▢ : 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 Dimensional Drawing

■ **2.4.1 External dimensions**
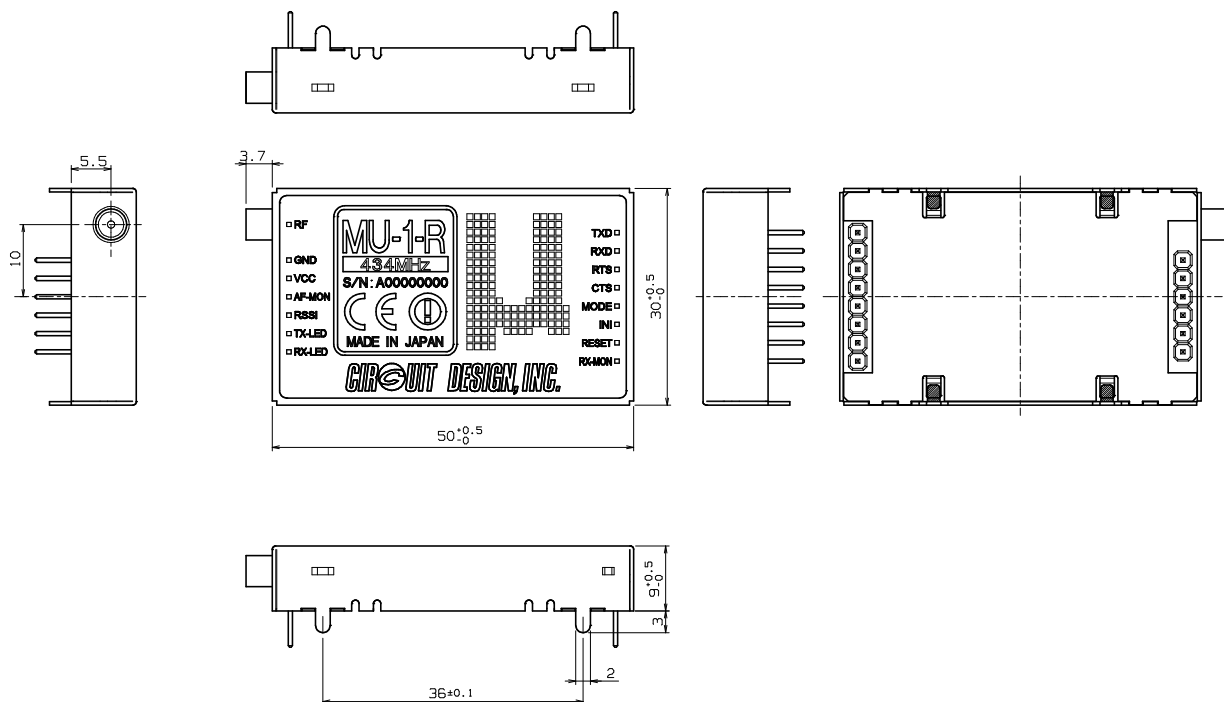


■ **2.4.2 Diagram of dimensions for hole positions**



Top view

*Same shape in 4 places*
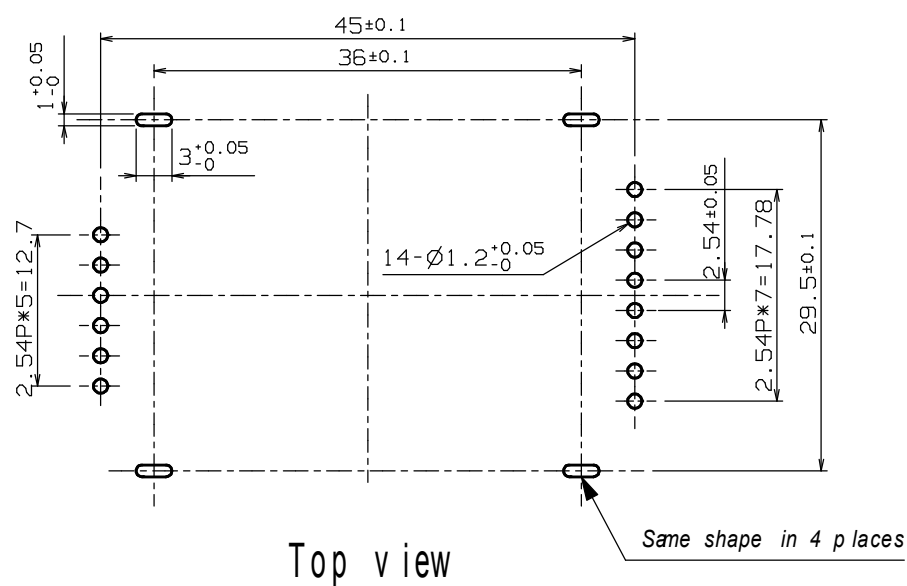
# Chapter 3 How to Design a User System

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 9 "Regulatory Compliance".

1. When using the MU-1, it is the user's responsibility to obtain the CE mark for the final product.
2. Refer to "9.1.2.1 Duty cycle and frequency channel" for selecting the MU-1 channel and setting the duty cycle.
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

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

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 46 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.
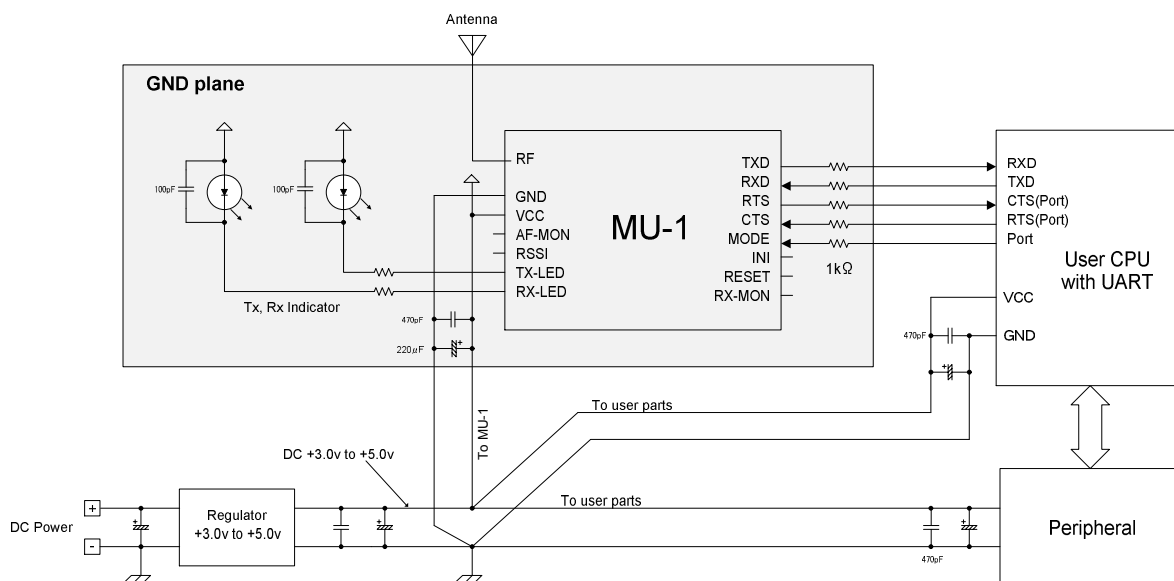
## 3.3. The Antenna

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 MU1

## 4.1 Communication & Links

### ■ 4.1.1 The transmit command format

There are 2 transmit commands for communication with the MU-1 that are used according to the purpose.

1. Control transmit command: Used mainly for system control.
2. Data transmit command: Used for transmitting system data.

With appropriate use of the control transmit command and data transmit command, it is possible to write a flexible system program. The basic way of using both commands is the same. The user can freely decide the format of either command.

In addition, since the received signal level of the received data is included at the front of the receive response of the target station of both transmit commands, it can be useful for deciding the transmission path.

There are three ways that the MU-1 processes transmit commands, as follows.

1. Transmission based on route information preset in the route register.
2. Transmission based on route information directly entered in the transmit command.
3. Transmission based on the Destination ID when the route register is not set.

However, there is no control transmit command with the method of transmission based on the Destination ID. Use either the route register information method or entering the command directly.

**1. The control transmit command**

Command option character for the control transmit command: '%'

Target station response characters: '\*DC'

Received signal level of the received packet: Always attached to the front of the response

**2. The data transmit command**

Command option character for the data transmit command: '/'

Target station response characters: '\*DR'

Received signal level of the received packet: Attached to the front of the response when specified with the '@SI' command

Example: Transmission with the control transmit command
Transmit the 10-byte (0Ah) control '0123ABC$#4' to target station ID = 8F via relay station IDs = 01, 02, 03. The source station Equipment ID = 5F.

- Source station 5F status
  Transmit command: @DT 0A 0123ABC$#4 %A 01,02,03,8F CRLF or @DT 0A 0123ABC$#4 %A CRLF

  Transmit response:      \*DT = 0A CRLF

- Target station 8F output

  When RI = OF        \*DC = 45 0A 0123ABC$#4 CRLF

  When RI = ON        \*DC = 45 0A 0123ABC$#4 /R 5F,01,02,03 CRLF

\* '45h' at the front indicates the signal level of the received packet. In this case, it is -69 dBm (45h).
For details of the value, refer to the 'RA' command.

■　**4.1.2 Communication**

'Data' in this explanation means either system data or system controls.
To perform communication, first set the link parameters for each station, then issue the transmit command.
For example, we will explain how to transmit the 5-byte data 'ABCDE' from source station No.01 via relay stations Nos.02 and 03 to target station No.04.

Transmit data 'ABCDE' to the target station with the Equipment ID No.04

ACK　　　ACK response

| User controller | Source station | Relay station EI=02 | Relay station EI=03 | Target station EI=04 | User controller |

Source station settings
EI=01, route information=02,03,04

Data transmission procedure
1. Set all MU-1 units in the system to the same User ID and Group ID
2. Set each Equipment ID (EI)
3. Set the route information in the route register with the RT command: @RT02,03,04

Route register content ｜ 02 ｜ 03 ｜ 04 ｜　｜　｜　｜　｜　｜　｜

　*Enter the target station Equipment ID at the end of the route information.

4. Transmit the data with the DT command
　－ Transmission based on the route register route information: @DT05ABCDE/R
　－ Transmission by directly entering the route information in the DT command: @DT05ABCDE/R02,03,04

*Link parameters
　UI = User ID
　GI = Group ID
　EI = Equipment ID
　DI = Destination ID
　RT = Route information
*When the relay function is not used, set the DI for transmission.
*When only 1 Equipment ID is set in the route information, that becomes the target station.(The same with DI)

In order to perform data transmission, it is necessary first to set the link parameters for all equipment within the system, however within the link parameters, all the equipment should be set to the same User ID and Group ID. In addition, if all the equipment is not set to the same channel, no link will be made. Set a different Equipment ID for all the equipment.
The setting items for each station are as follows.
・　Relay station and target station: Channel, User ID, Group ID, Equipment ID
・　Source station:
　Channel, User ID, Group ID, Equipment ID, route information or Destination ID
The data is transmitted from the source station towards the target station set in the route information or the Destination ID.

When the '@DT' command is executed inside the MU-1, the route information is referenced, but there are two reference methods as follows.
・　Transmission based on route information set in the route register　　　　Example: @DT 05 ABCDE /R
・　Transmission based on route information directly entered in the '@DT' command.　　　　　　　Example: @DT 05 ABCDE /R 02,03,04

In addition, for communication with only 1 hop, issue the '@DT' command after performing any of the following settings.
・　Disable the route register and set the target station ID as the Destination ID
　　　　Example: @RT NA, @DI xx: @DT 05 ABCDE
・　Set only the Equipment ID of the target station in the route register
　　　　Example: @RT xx: @DT 05 ABCDE /R

Route information is set in the route register using the '@RT' command. The route information lists the Equipment IDs of the relay stations, however at the end of the information the Equipment ID of the target station is specified. The MU-1 relay function does not perform retry between each station for data. The data from the source station is transmitted at once through to the target station. When reliability is required for data transmission, use the '@DT' command that has an ACK response.

■   **4.1.3 The link parameters**

In order to transmit and receive data, the MU-1 has the following link related parameters.
Link parameters can be specified easily with commands, and they can be changed each time a data frame is sent.
In addition, if the source station, relay station, and target station do not all use the same channel, no link will be made.

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 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 source station, enter the Equipment ID of the target station at the end of the route information or 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, irrespective of the Equipment ID (Broadcast). If DI = FFh is specified, the data is sent but no station will receive it.

5. RT: Route information
   This indicates the route to the target station. The route information lists the Equipment IDs of the relay stations and the Equipment ID of the target station. There are two ways to issue data transmission commands using relay stations, as follows.
   ・ Transmission based on route information set in the route register with the '@RT' command
   ・ Transmission with the route information entered directly in the data transmission command

\* The method of transmission based on the Destination ID is a transmission method for when no relay station is used. In this case, the control transmit command cannot be used. To use the control transmit command when relay stations are not used, use the method of transmission based on the content of the route register. In other words, write the Equipment ID of only one target station in the route register

■   **4.1.4 Conditions for establishing a link**

A link is established for communications when the following conditions are met simultaneously.
1. There are no errors in the received frame
2. The User ID and Group ID match between the sending and receiving units.
3. The Equipment ID specified in the route information or Destination ID of the frame and the Equipment ID of the target station match
4. The channel used is the same

## 4.2 System Configuration (When the Relay Function is Not Used)

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.
With 1 hop communication, the Destination ID is specified for communication, however in this case set the route register to "relay function disabled = 'NA'" using the '@RT' command.

**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 source station and the Equipment ID of the target 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.
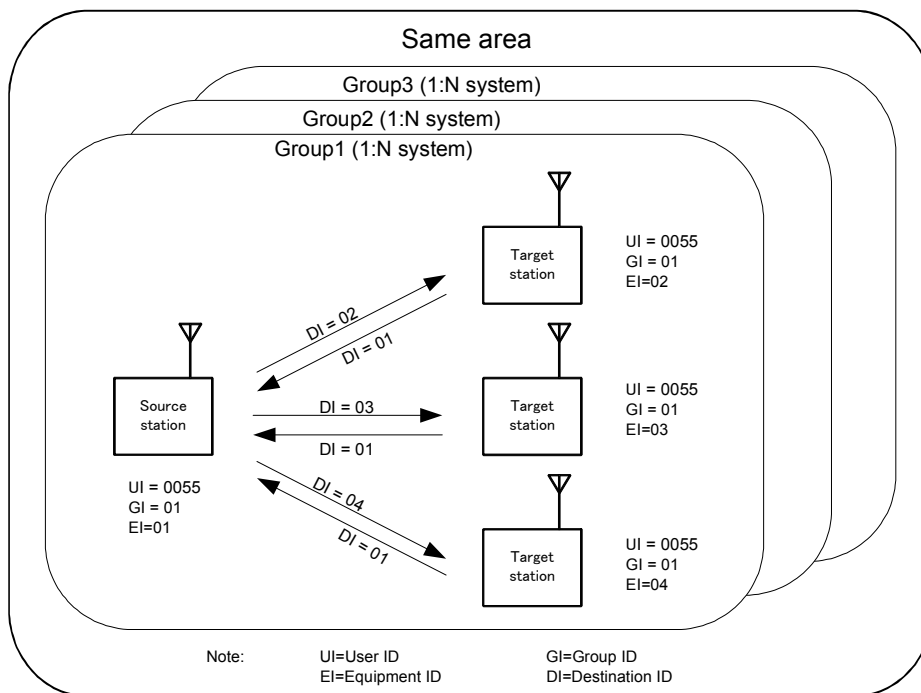


**Communication between groups**
By changing the Group ID for transmitting, it is possible to communicate with another group.

**Broadcast communication**
If the Destination ID is specified as 00h at the source station and data is transmitted, all target stations will receive the data at the same time, irrespective of the Equipment ID.

## 4.3 System Configuration (When the Relay Function is Used)

With 1 hop communication, the Destination ID is used as a link parameter, however with multi-hop communication using the relay function, data is transmitted based on the route information set in the route register with the '@RT' command or based on route information entered directly in the '@DT' command. The data transmission command is '@DT', however when using the relay function, specify an option at the end of the command. The content of the Destination ID is ignored.

### ■ 4.3.1 Transmission with the route register route information

The diagram below is an example of transmission based on route information set in the route register. Route information is set only in the source station. In this case, use only the command option '/A' for the '@DT' command.



Relay System Example 1 (Route information specified in the route register, with ACK response)
Command: @DT05ABCDE/A or @DT05ABCDE%A

Note: UI = User ID,  GI = Group ID,  EI = Equipment ID,  DI = Destination ID,  RT = Route information
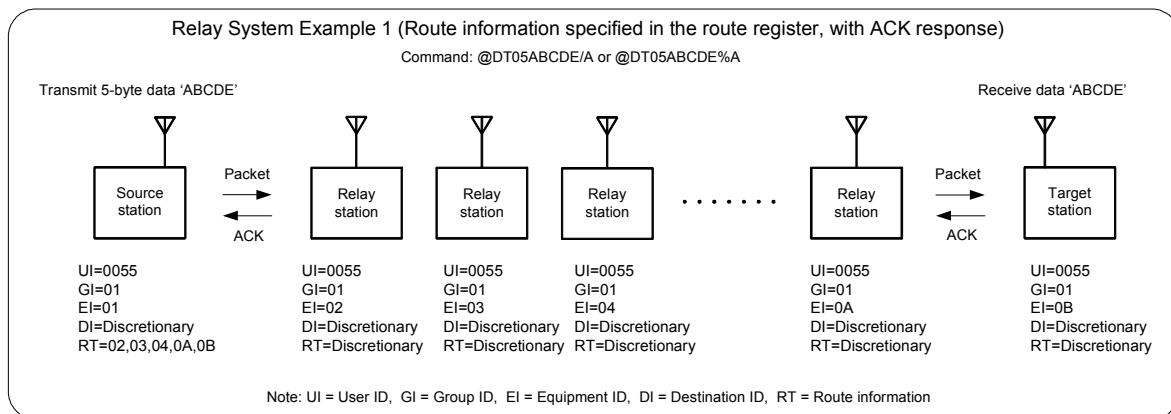
### ■ 4.3.2 Transmission with the route information entered in the transmit command

The diagram below is an example of transmission with the route information entered directly in the command option line of the '@DT' command. Enter the route information in the '@DT' command issued after '/A'. In this case, the route information set in the route register is ignored.



Relay System Example 2 (Route information entered directly in command, with ACK response)
Command: @DT05ABCDE/A02,03,04,0A,0B or @DT05ABCDE%A02,03,04,0A,0B

Note: UI = User ID,  GI = Group ID,  EI = Equipment ID,  DI = Destination ID,  RT = Route information
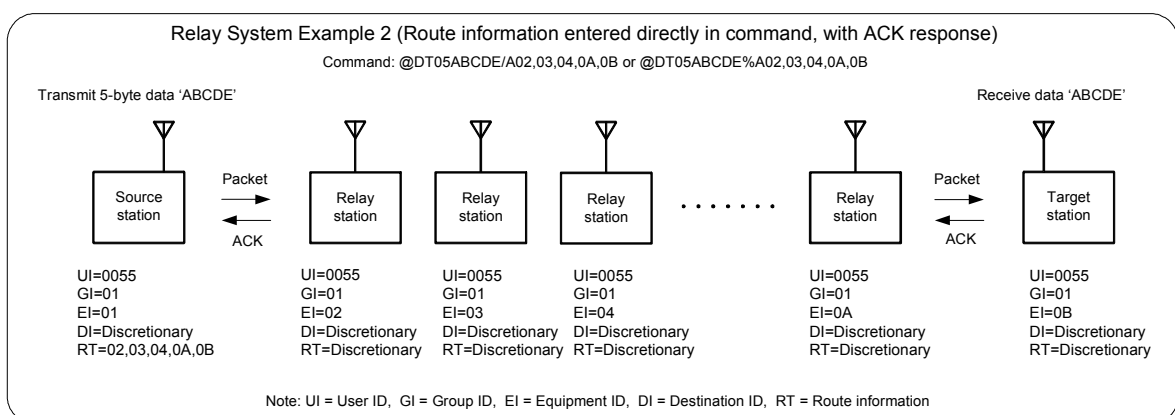
### ■ 4.3.3 1:N relay system

The diagram below shows a 1:N system using the relay function, in which communication is performed with several target stations at a remote location.

In the diagram, the route information is entered directly in the transmit command, however communication is also possible using the route register content.

Relay System Example 3 (Route information entered directly, with ACK response, polling system)

Control transmission commands
Target station 1: @DT05ABCDE%A02,03,08,0A
Target station 2: @DT05ABCDE%A02,03,08,0B
Target station 3: @DT05ABCDE%A02,03,08,0C

Receive data 'ABCDE'

Transmit 5-byte data 'ABCDE'

Source station
Relay station 1
Relay station 2
Relay station 3
Target station 1
Target station 2
Target station 3

Packet
ACK

UI=0055
GI=01
EI=01
DI=Discretionary
RT=Discretionary

UI=0055
GI=01
EI=02
DI=Discretionary
RT=Discretionary

UI=0055
GI=01
EI=03
DI=Discretionary
RT=Discretionary

UI=0055
GI=01
EI=08
DI=Discretionary
RT=Discretionary

UI=0055
GI=01
EI=0A
DI=Discretionary
RT=Discretionary

UI=0055
GI=01
EI=0B
DI=Discretionary
RT=Discretionary

UI=0055
GI=01
EI=0C
DI=Discretionary
RT=Discretionary

Packet
ACK

Note: UI = User ID, GI = Group ID, EI = Equipment ID, DI = Destination ID, RT = Route information

### Broadcast communication

If data is transmitted after Equipment ID = 00h as the last number in the route of the source station route information settings, all target stations will receive the data at the same time, irrespective of the Equipment ID.

The command for the system in the diagram above is as follows.

Control transmit command: @DT 05 ABCDE %R 02,03,08,00

However, note that the data is transmitted in a range to which the radio waves reach from the last relay station (relay station 3). In other words, relay station 2 also receives the data at the same time.

Also, do not use commands with ACK responses (command options: /A, /B, %A, and %B) in the transmit command since these cause radio wave collisions.

## 4.4   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.

⚠ Note          When configuring your system, ensure that the source station and target station are in the same mode. In addition, ensure that the relay station is in the command mode.

■   **4.4.1 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. Changing the parameters, mode, and channel of the main unit cannot be performed in the binary mode or text mode. Consider how to enable mode switching at the hardware design stage. Control of the radio component is performed automatically by the MU-1, so you do not need to pay attention to this aspect.

255 bytes of user data can be sent at one time.
For data, the data transmit command is used, and for system control, the control transmit command is used. The data transmit command is mainly used for data transmission. The user can freely decide the format of the control transmit command, and it can be used for system control.
Among data transmit commands and control transmit commands, there are types of command that return an ACK response.
In addition, it is possible to output the same data or control from the relay station as from the target station. This makes it possible to synchronize the system.

When data is received, since only correctly received data is output to the user application as a receive response, it is processed on the user side.

■   **4.4.2 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. Always add the CRLF code as a terminator at the end of the character string. When the MU-1 detects this terminator, it starts data transmission. Ensure that the maximum number of characters input is within 255 bytes. The CRLF code (0Dh, 0Ah) and Esc code (1Bh) cannot be sent by radio. However, the CRLF code is attached to the end of the data output from the target station as a terminator.

■   **4.4.3 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 (max. 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.

■   **4.4.4 Mode setting**

**When the MODE terminal is at Low level**
1. In the command mode if the '@MD TX' 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 '@MD BI' 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



*1: When the mode is set in the RAM    *2: When the mode is fixed in the EEPROM
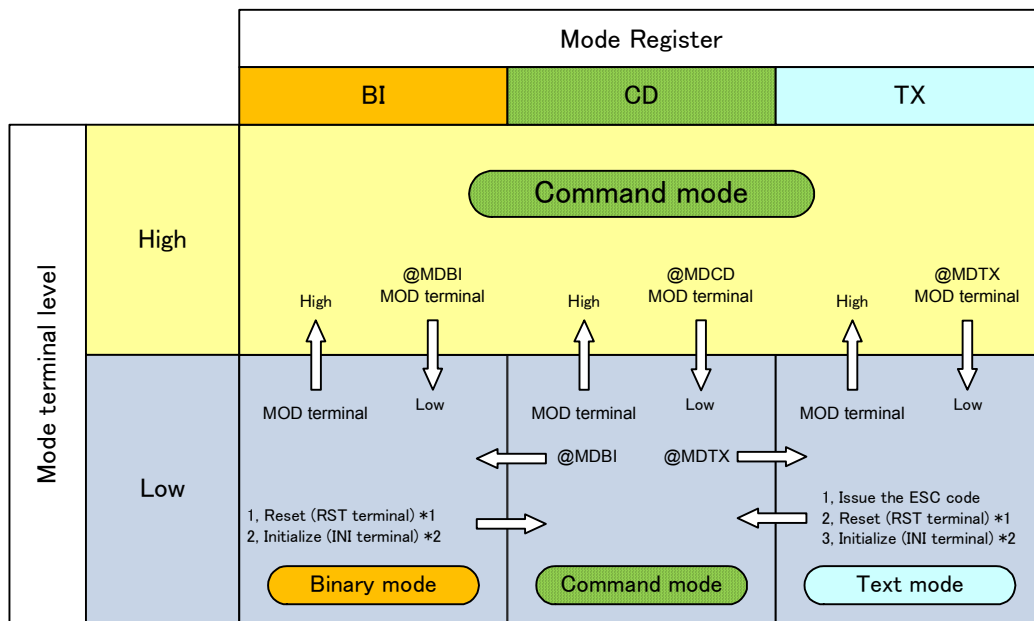
**\* BI:** Binary mode          **CD:** Command mode          **TX:** Text mode

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

## 4.5 Resetting

If you are uncertain about the various settings of the MU-1, return them to the settings at the time the power is turned on.

◆ The internal CPU is reset by any of the following.
1. Set the reset terminal of the MU-1 to 1 ms period Low level.
2. Issue the software reset command '@SR'.
3. The target station can be reset using an extended command.

## 4.6 Initializing

Return the unit to the factory default settings if communication with the MU-1 is not possible or if you are uncertain of the internal settings.

◆ The internal CPU is initialized with any of the following.
1. Set the INI terminal of the MU-1 to Low level and turn on the power. Then turn off the power, and turn it on again.
2. Issue the initialize command '@IZ'. After issuing it, always issue the software reset command '@SR'.
◆ After initialization the main parameter values (default values) are as follows. For details of the default values, refer to each command in the manual.

1. Link parameters
   User ID: UI = 0000, Group ID: GI = 00, Equipment ID: EI = 01, Destination ID: DI = 01, Channel = 7 channel, route information = NA (disabled)
2. UART parameters
   Baud rate = 19,200 bps, parity = none, stop bit = 1
3. Internal operation parameters
   Mode = command

## 4.7 Assessing the Field Status for Communication

With applications that use the MU-1, in the development stage or when development is complete and the unit is actually used, it is necessary to assess the field status of the system at all times for stable communication. In other words, in the development stage when the MU-1 is mounted on the circuit board, it is necessary to consider the pattern design and arrangement of components to extract the optimum values for radio performance, and to ensure stable and reliable communication in operation, it is necessary to measure the state of the radio waves and the surrounding floor noise and to locate the equipment at the optimal point.

The MU-1 has the following commands to allow convenient assessment of these aspects of communication.

1. @RA: Acquisition of the RSSI absolute level of the source station
2. @CR: Acquisition of the RSSI absolute level of the target station (actual signal level and floor noise level)
3. @CP: Packet test

### ■ 4.7.1 Source station RSSI measurement

By issuing the @RA command, the RSSI level of the source station can be measured. It is possible to achieve optimization while measuring the high frequency noise from the unit itself and from peripheral equipment, and the signal level from the source station. To measure the signal level from the target station, it is possible to issue a command requesting continuous issue of data (@DT 05 @CT xx) from the source station to the target station.



@RA: Acquire source station RSSI
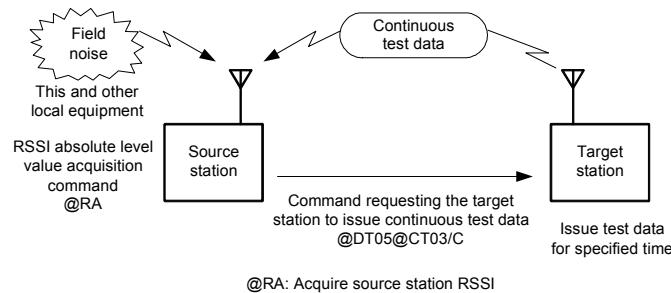
### ■ 4.7.2 Target station RSSI measurement

In order to perform stable communication, it is necessary to locate the equipment where a sufficiently high signal level can be obtained.

By issuing the @CR command, it is possible to measure the floor noise of the target station and the signal level from the source station and send the information back.



@CR: Acquire target station RSSI
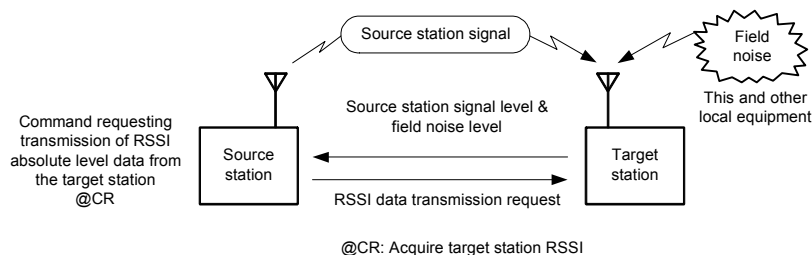
### ■ 4.7.3 Packet test

Using the @CP command and by issuing actual data packets, it is possible to assess the field status between the target station. A data size between 0 to 255 bytes can be set for each packet with the @CP command. In order to locate the equipment in the optimum place, send packets repeatedly with the @CP command and measure the packet success rate.



@CP: Packet test
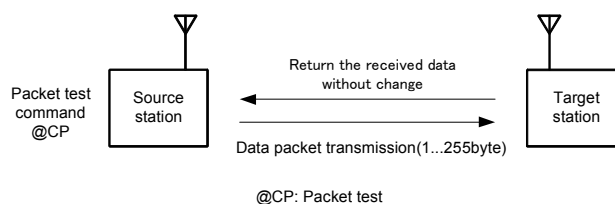
## 4.8 Changing Channels

It is possible to change the channels used when the system is in operation.
This can be done by changing the channels of specified target station individually, or by changing the channels of all stations specified in the route information at once.
The channel changing function uses radio commands. Before changing the channel, always check that a data link is possible. However, since wireless errors may also occur in this case, changing the channel may not always be possible. Exercise prudence when changing channels.

### ■ 4.8.1 Changing channels individually

Using the extended command '@DT 05 @CHxx /C' it is possible to change the channel of specified stations. For the source station channel, use the @CH command. Start changing the channels of the equipment located furthest away.

Change the channels of target station EI=0A to 2E
Command: @DT@CH2E/C02,03,04,0A

| Source station | | Relay station | Relay station | Relay station | | Target station |
|---|---|---|---|---|---|---|
| EI=01 | → | EI=02 | EI=03 | EI=04 | → | EI=0A |
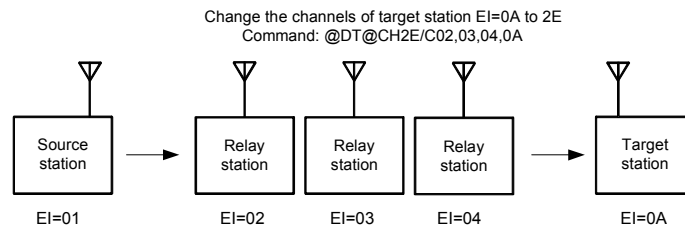
### ■ 4.8.2 Changing all channels at once

Using the extended command '@DT 05 @CHxx /F' it is possible to change the channels of the relay stations and target stations specified in the route information and the channel of the source station. The timing by which the channels of the relay station and source station are changed is the moment when, after the channel changing command reaches the target station, the ACK responses output from the target stations are received by the various stations. Before changing the channel, always check that there is a data link.

Change all channels at once to 2E
Command: @DT05@CH2E/F02,03,04,0A

| Source station | Change request | Relay station | Relay station | Relay station | ACK | Target station |
|---|---|---|---|---|---|---|
| EI=01 | | EI=02 | EI=03 | EI=04 | | EI=0A |
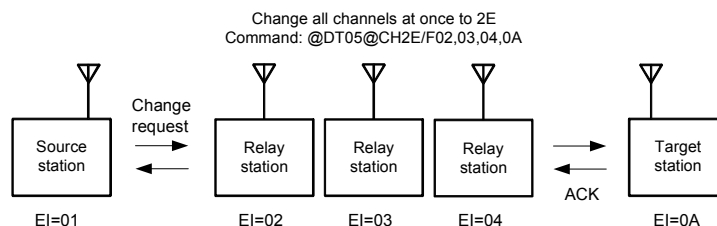
# Chapter 5 How to Develop a Program

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.
This chapter 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 Outline of User Processes

The outline of how the user controls the MU-1 is explained using one-way communication as an example.
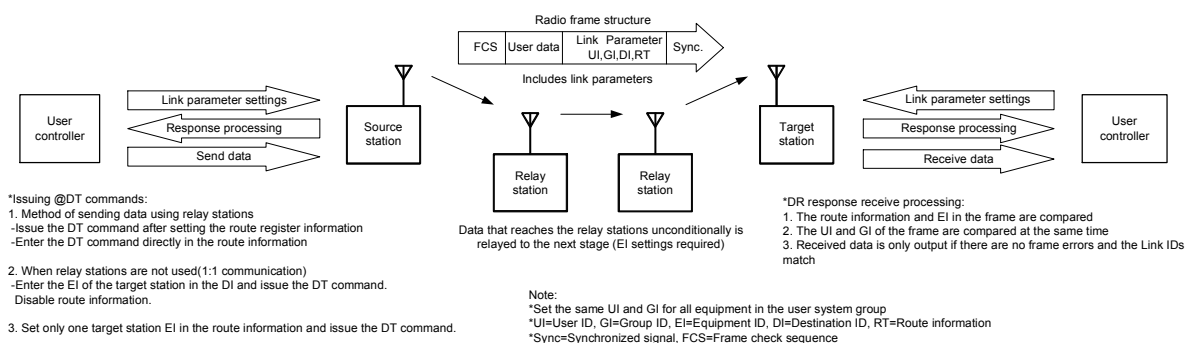


When using the MU-1 to transmit data, it is first necessary to perform various initial settings. When an MU-1 setting command is issued, a command response corresponding to the command is always returned from the MU-1. Process the command response as necessary. In addition, when data is received from the source station, a receive response ('*DR') is output from the MU-1, and receive processing is performed according to its data size.
In order for the target station to receive the data transmitted from the source station, it is necessary to set the link parameters. When the '@DT' command is issued, the link parameters are placed in the actual wireless data frame and are processed appropriately by each station. Since the data is not addressed to it, the relay station simply relays the data unconditionally. If there is no data error, it is output to the user controller by the target station as the *DR receive response.
In order to ensure reliable transmission of data, use the '@DT' command that has an ACK response.
In addition, when the status of radio waves in the channel being used is poor, it is possible to change the channel of each station using the relay function with an extended command.
There is also a convenient '@DT' command for outputting the same user data from the relay stations as well.

## 5.2 The Operations of the MU-1

1. The radio transmission rate 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.

## 5.3   Command Transmission

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

■   **5.3.1 Issuing commands**

It is possible to feed the characters of a command such as '@CH 03 CRLF'to UART sequentially.
* @: @ (40h) = prefix          CRLF: CR (0Dh) = carriage return, LF (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 '@CH 20CRLF'
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.

■   **5.3.2 Issuing data transmit commands**

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

Make the command string '@DT 05 #%&45 CRLF'.
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.

■ **5.3.3 Issuing commands continuously**

You cannot issue commands successively as in '@CH03C<sub>R</sub>L<sub>F</sub>@EI33C<sub>R</sub>L<sub>F</sub>@DI05C<sub>R</sub>L<sub>F</sub>'. 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 '@CH 03 C<sub>R</sub>L<sub>F</sub>'.        Confirm (process) the response '*CH = 03 C<sub>R</sub>L<sub>F</sub>'
2. Issue the command '@EI 33 C<sub>R</sub>L<sub>F</sub>'.        Confirm (process) the response '*EI = 33 C<sub>R</sub>L<sub>F</sub>'
3. Issue the command '@DI 05 C<sub>R</sub>L<sub>F</sub>'.        Confirm (process) the response '*DI = 05 C<sub>R</sub>L<sub>F</sub>'

Process for issuing commands continuously

Preparation
1. Create a transmit command string
   Example:  @EIFF + CRLF
             @CH00 + CRLF
             @RA + 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

@RA + CRLF

@CH00 + CRLF

@EIFF + CRLF

*Command strings transmitted in order*
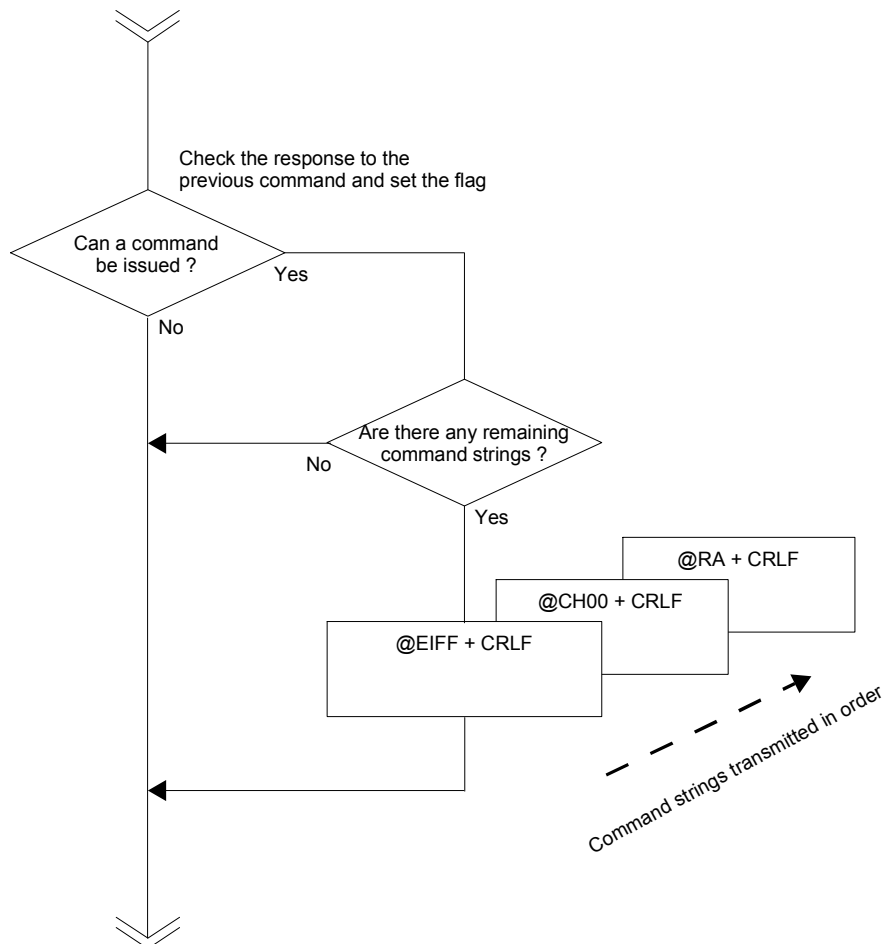
■ **5.3.4 Issuing commands continuously (when ignoring the response)**

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.

## 5.4 Response Processing

■ **5.4.1 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)
3. When control is received from other radio equipment within the system (receive response = '*DR' response)
Process items other than the receive response as necessary.

■ **5.4.2 Response format**

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 CRLF (0Dh, 0Ah) is appended.

   Example:   *CH = 1B CRLF          *EI = 30 CRLF        *DR = 0B 66666666666 CRLF

■ **5.4.3 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
   DT, GI, EI, DI, CH, RS, MD, BR, SB, PB, TC, TB, CT, RM, VR, ER, SG, SR, IZ, RA, CP, CA, CR, SI, RR
   Example: Command '@CH 2A CRLF'    Response: '*CH = 2A CRLF'
       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 '@UI 800F,xxxx CRLF'        Response: '*UI = 800F CRLF'
       The value '800F' consists of 4 ASCII characters that express a hexadecimal number.
3. DR response: Response when data is received by wireless
   Example: When a reception response with a 10 (0Ah) value is received.
       Response '*DR = 0A 5555555555 CRLF'
       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.
4. DC response: Response when control is received by wireless
   Example: When a reception response with a 10 (0Ah) value is received.
       Response '*DC = 0A 5555555555 CRLF'
       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. Number of channels × 2 character response: 64 ch × 2 = 128 character response
   RC
6. 9 character response: The response parameter is a 9 character response
   SN
7. Items for which the response length cannot be regulated
       The response length for RT and VR cannot be regulated.
       These should be determined by their terminator.

■  **5.4.4 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']

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 in loop mode(LM=0)

# Response processing of commands

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

Is there data in RB?
— No
— Yes

What is the current LM?

LM0 | LM1 | LM2 | LM3 | LM4

Response type determination RES

RB read '*'?
— No
— Yes

RD=RB read
RES=RD

RD=RB read
RES=RES+RD

RB read '='?
— No
— Yes

What is the response type?

2-character response
GI,EI,DI,CH,RS,
BR,CT,VR etc.

4-character response
UI

DC response

DR response
(When SI=OF)

DS response
(When SI=ON)

LM=0 | LM=1 | LM=2 | LM=3 | LM=0 | LM=4 | LM=10 | LM=20 | LM=30 | LM=40 | LM=50

LM=140, 150 | LM=130 | LM=110, 120 | LM processing concept | LM=10 | LM=20 | LM=30 | LM=40 | LM=50

DR & DS response processing

Acquire amount of data
Convert from ASCII characters
to numerical value

Divide amount of data and
acquire data

DC response processing

Acquire amount of control data
Convert from ASCII characters
to numerical value

Divide amount of data and
acquire data

Processing according to
control

4-character response
processing

2-character response
processing

Process while
setting LM

LM=**

Read the
2-character value
while setting LM

Read the
4-character UI
while setting LM

Read the 2-character
RSSI information
while setting LM

Read the 2-character
RSSI information
while setting LM

Read the
2-character size
while setting LM

Read the
2-character size
while setting LM

Read the
2-character size
while setting LM

LM=0 | LM=0 | LM=0 | LM=110 | LM=120 | LM=130 | LM=140 | LM=150

## 5.5 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 '@RA' 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 ID=FFh, data cannot be transmitted, and when the Equipment ID is EI=FFh, even if the link parameter matches, received data is not output. Instead, the RSSI (radio field intensity) of the current channel can be read out with the '@RA' command.

The procedure is as follows.
1. Issue the command '@EI FF CRLF'.
   This setting is made only once at the beginning.
2. Issue the command '@CH xx CRLF'.
   Designate a channel for which to acquire the RSSI level. 'xx' is the hexadecimal value that indicates the channel.
3. Issue the command @RA CRLF
   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 '@RA' command.

## 5.6 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, it is performed using two-way communication such as ARQ (Automatic Repeat Request), and it is necessary to provide measures against dropped frames caused by wireless errors. Data frames include frame numbers and the like, and these are used as the criteria for ARQ.

## 5.7. 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.

### ■ 5.7.1 Modes

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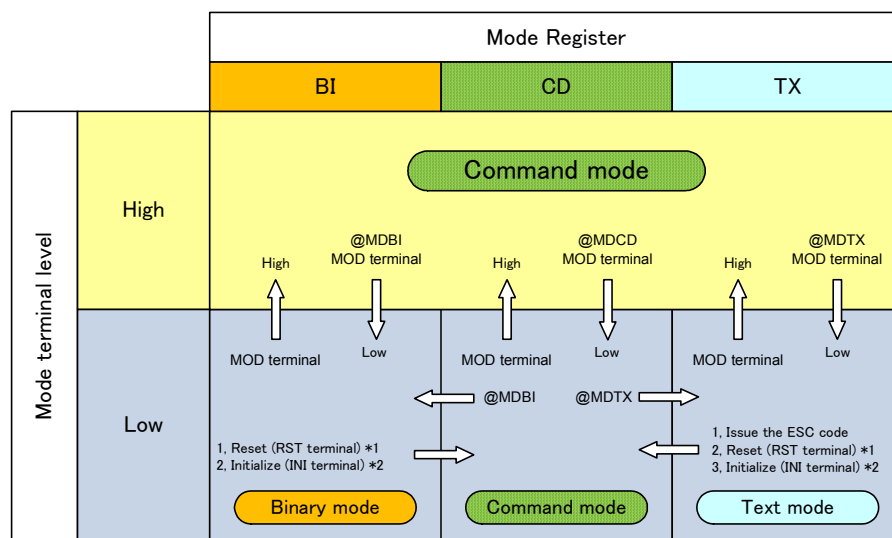


*1: When the mode is set in the RAM   *2: When the mode is fixed in the EEPROM

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 '@MD BI' 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 '@MD BI' command.
    In the text mode: Issue the escape code: 'ESC' and after setting the MU-1 to the command mode, switch modes.

■  **5.7.2 When developing a new system**

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 "@MD BI /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.
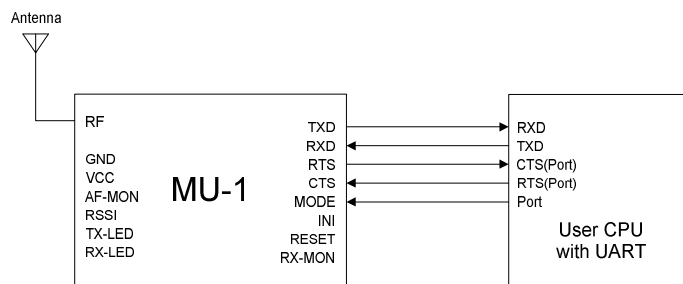


When not using hardware flow control
1. Set the CTS terminal to L level, and open the RTS terminal.
2. Set the UART of the control CPU to no flow control.
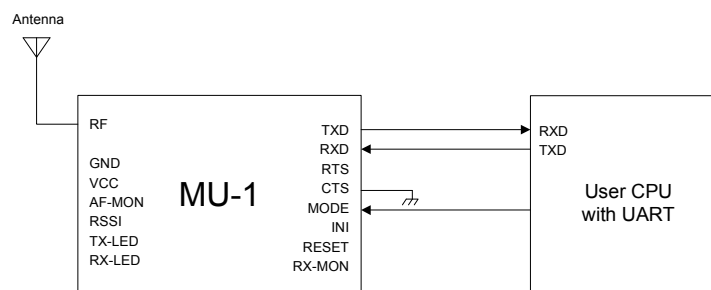
■ **5.7.3 When using only the data line of existing equipment**

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 interface 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.
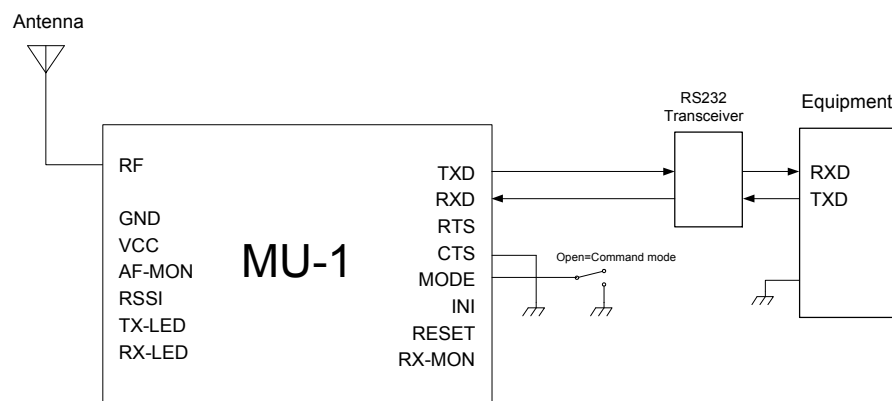


* The MODE terminal is pulled up internally.

■ **5.7.4 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 Command and Response Types

The following types of MU-1 command and response are possible.

1. Transmit command and transmit response:
   Command and response issued for transmission of system data and system controls.
2. Receive response:
   The response when data is received due to the transmit command issued by the source station.
3. Control command and control response:
   Command issued to control the MU-1, and its associated response.
4. Test command and test response: Command issued to execute a variety of test functions, and its associated response.
5. Extended command and extended response: Command issued to execute extended functions, and its associated response.
6. 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)

## 6.2 Command and Response Table

\* In the table below, XX and XXXX are 2 and 4 digit hex values respectively. w indicates ASCII characters or byte data.

■   **6.2.1 Transmit command and transmit response**

| Command type | Function | Command | Response |
|---|---|---|---|
| Transmit command | Data transmit command (no relay function) | @DT XX ww…ww | *DT = XX |
| | Data transmit command (relay function, no ACK) | @DT XX ww…ww /R [*1] | *DT = XX |
| | Data transmit command (relay function, ACK) | @DT XX ww…ww /A [*2] | *DT = XX |
| | Control transmit command (relay function, no ACK) [*5] | @DT XX ww…ww %R [*3] | *DT = XX |
| | Control transmit command (relay function, ACK) [*6] | @DT XX ww…ww %A [*4] | *DT = XX |

\*1, 2: There are options /S and /B that output user data at relay stations.
\*3, 4: There are options %S and %B that output user control data at relay stations.
\*5, 6: The control transmit command is a transmit command that the user can use freely for system control. The basic method of use is the same as for data transmit commands.

■ **6.2.2 Receive response**

| Response type | Function | Response | Corresponding command |
|---|---|---|---|
| Receive response | Control receive response | *DC = xx XX ww...ww | DT....% |
| | Data receive response | *DR = XX ww...ww *1 | DT..../ |
| | Data receive response with RSSI information | *DS = xx XX ww...ww *2 | DT..../ |

*1: When the mode setting with RF received signal level information SI is OF.
*2: When the mode setting with RF received signal level information SI is ON.

■ **6.2.3 Control commands and control responses**

| Control command type | Function | Command | Response |
|---|---|---|---|
| Radio link related setting and acquisition commands | User ID setting | @UI XXXX,XXXX | *UI = XXXX |
| | Group ID setting | @GI XX | *GI = XX |
| | Sets the Equipment ID | @EI XX | *EI = XX |
| | Destination ID setting | @DI XX | *DI = XX |
| | Relay route designation | @RT XX,XX,..,XX | *RT = XX,XX,..,XX |
| | Sets the channel to use | @CH XX | *CH = XX |
| UART parameter setting commands | Sets the UART baud rate | @BR ww | *BR = ww |
| | Sets the UART parity | @PB ww | *PB = ww |
| | UART stop bit setting | @SB ww | *SB = ww |
| Operation setting and information acquisition commands | Sets the operation mode | @MD ww | *MD = ww |
| | Sets the command mode input waiting time | @TC XX | *TC = XX |
| | Time without input in the binary mode setting | @TB XX | *TB = XX |
| | Link data continuous transmission | @CT ww | *CT = ww |
| | Attach route information mode setting | @RI ww | *RI = ww |
| | Sets the response display mode | @RM ww | *RM = ww |
| | Acquires the ROM version | @VR | *VR = XX ww...ww |
| | Acquires the serial number | @SN | *SN = wwwwwwww |
| | Reset | @SR | *SR = 00 |
| | Initialize | @IZ | *IZ = 00 |
| | Mode setting with RF received signal level information | @SI ww | *RI = ww |
| | Receive route information use setting | @RR ww | *RR = ww |

■ **6.2.4 Test command and test response**

| Command type | Function | Command | Response | Receive response |
|---|---|---|---|---|
| Test commands | RSSI absolute level measurement | @RA | *RA = XX | No |
| | Target station all channel RSSI absolute level measurement | @CA | *CA = 00 | Yes |
| | Target station RSSI absolute level measurement | @CR | *CR = 00 | Yes |
| | All channel RSSI absolute level measurement | @RC | *RC = XX...XX | No |
| | Packet test | @CP XX ww...ww | *CP = XX | Yes |

* RSSI: Received Signal Strength Intensity

■ **6.2.5 Extended command and extended response**

| Command type | Function | Command | Response | Receive response |
|---|---|---|---|---|
| Extended command | Changes the target station channel | @DT 05 @CHXX /C | *DT = 05 | Yes |
| | Changes the target station channel and fixes the change in internal EEPROM | @DT 07 @CHXX /W /C | *DT = 07 | Yes |
| | Changes the channels of multiple stations at once | @DT 05 @CHXX /F | *DT = 05 | No |
| | Changes the channels of multiple stations at once and fixes the changes in internal EEPROM | @DT 07 @CHXX /W /F | *DT = 07 | No |
| | Issues target station test data | @DT 05 @CTXX /C | *DT = 05 | No |
| | Resets the target station | @DT 03 @SR /C | *DT = 03 | Yes |
| | Resets multiple stations at once | @DT 03 @SR /F | *DT = 03 | No |

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

## 6.3 Save Setting 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, RT, CH, BR, PB, SB, MD, TC, TB, CT, RI, RM, SI, RR

Example: Fix the User ID as 0000h (UI=0000 is for testing)

Control command: @UI 0000,0B27 /W CRLF

Control response: *WR = PS CRLF
                  *UI = 0000 CRLF

Example: Sets the channel to ch16 and fix it.

Command to the MU-1: @CH 10 /W CRLF

Response from the MU-1: *WR = PS CRLF
                        *CH = 10 CRLF

⚠️ Note | 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.

## 6.4 Command and Response Details

■ **The default value**

"Default" value found in "Command and Response Details" is the factory setting set using the 'INI' terminal or by issuing the initialize command.

■ **6.4.1 Transmit command and transmit response**

• **Command basic format**

Prefix + command name + value + data + command option + terminator (= 'CRLF')

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.
Data: Byte sequence of user data.
Command option: Specifies the operation of the command and route information.
Terminator: A code that indicates the end of the command 'CRLF' (0Dh, 0Ah).

Example command

| Command string | Hexadecimal code actually sent to the MU-1 |
|---|---|
| @DT 06 abc123 CRLF | 40,44,48,30,36,61,62,63,31,32,33,0D,0A |

• **Response basic format**

Prefix + command name + '=' + value + terminator (= 'CRLF')

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.
Terminator: A code that indicates the end of the command 'CRLF' (0Dh, 0Ah).

Command response example (255-byte data transmission)

| Response character string | Hexadecimal code actually issued from the MU-1 |
|---|---|
| *DT = FF CRLF | 2A,44,54,3D,46,46,0D,0A |

■ **6.4.1.1 @DT.../ data transmit command**

Note that the format and operation of the data transmit command 'DT.../' is different depending on whether or not the relay function is used.

In addition, there is also a method of notation where the data transmit command makes the target station return data receive acknowledgement (ACK).

**1. When the relay function is not used**

'@' + 'DT' + data size + data + 'CRLF'
- Data size is specified by 2 hexadecimal ASCII characters. The maximum data size that can be sent at one time is 255 bytes.
- The data is a numerical value up to 00h to FFh.
- The data is sent to the target station set in the Destination ID: DI.

When the source station MU-1 receives the '@DT' command from the controller, it performs wireless data transmission and returns a response to the controller at the same time. The target station MU-1 outputs the data in the DR response format.

Format '@DT' ss DD….D 'CRLF'
    ss: Shows the data size in 2 hexadecimal digits Value: 00h to FFh
    DD…D: D expresses 1-byte data. Value: 00h to FFh, amount of data: maximum 255 bytes

Example: Transmit the 10 bytes of data (0Ah) '0123ABC%#$' to the target station set in the Destination ID.   The target station Equipment ID = 01h. The source station Equipment ID = 5Fh.

- Source station 5F status
  Transmit command: @DT 0A 0123ABC%#$ CRLF
  Transmit response: *DT = 0A CRLF

- Target station 01 output
  Receive response: *DR = 0A 0123ABC%#$ CRLF    * Does not depend on the RI setting

**2. When the relay function is used (receive confirmation acknowledgement: no ACK)**
With this command, data is transmitted using the relay function.

Format 1: '@' + 'DT' + data size + data + '/R' + route information + 'C$_{RLF}$'
Format 2: '@' + 'DT' + data size + data + '/R' + 'C$_{RLF}$'


Details
    Format '@DT' ss DD….D '/R' rr,rr,…,rr 'C$_{RLF}$'
        ss: Shows the data size in 2 hexadecimal digits and ASCII characters Value: 00h to FFh, maximum 255 bytes
        DD…D: D expresses 1-byte data. Value: 00h to FFh, amount of data: maximum 255 bytes
        rr,rr,…,rr: Shows the route information in 2 hexadecimal digits and ASCII characters Value: 00h to FEh,
            number of relay stations maximum 10 units

- With Format 1, the route information is entered directly in the command.
- With Format 2, transmission is based on route information set in the route register with the RT command or on the content of the Destination ID. When entering the route information, enter the Equipment ID of the target unit at the end. If no route information is set (NA set for the RT command), the equipment set as the Destination ID will be the target station.
- To output the same data from all currently connected relay stations, issue the command with '/S' instead of '/R'.

Example: Transmit the 10-byte (0Ah) data '0123ABC%#$' to target station ID = 8F via relay station IDs = 01, 02, 03. The source station Equipment ID = 5F.

- Source station 5F status
  Transmit command: @DT 0A 0123ABC%#$ /R 01,02,03,8F C$_{RLF}$ or @DT 0A 0123ABC%#$ /R C$_{RLF}$

  Transmit response: *DT = 0A C$_{RLF}$


- Target station 8F output
  When RI = OF
  *DR = 0A 0123ABC%#$ C$_{RLF}$
  When RI = ON
  *DR = 0A 0123ABC%#$ /R 5F,01,02,03 C$_{RLF}$

**3. When the relay function is used (receive confirmation acknowledgement: with ACK)**

With this command, data is transmitted using the relay function, but it is possible to get data receive confirmation acknowledgement (ACK) from the target station.

Format 1: '@' + 'DT' + data size + data + '/A' + route information + 'CRLF'
Format 2: '@' + 'DT' + data size + data + '/A' + 'CRLF'

Details
Format '@DT' ss DD….D '/A' rr,rr,...,rr 'CRLF'
ss: Shows the data size in 2 hexadecimal digits and ASCII characters Value: 00h to FFh, maximum 255 bytes
DD…D:   D expresses 1-byte data. Value: 00h to FFh, amount of data: maximum 255 bytes
rr,rr,…,rr:   Shows the route information in 2 hexadecimal digits and ASCII characters Value: 00h to FEh, number of relay stations maximum 10 units

- With Format 1, the route information is entered directly in the command.
- With Format 2, transmission is based on route information set in the route register with the RT command or on the content of the Destination ID. When entering the route information, enter the Equipment ID of the target unit at the end. If no route information is set (NA set for the RT command), the equipment set as the Destination ID will be the target station.
- To output the same data from all currently connected relay stations, issue the command with '/B' instead of '/A'.

Example: Transmit the 10-byte (0Ah) data '0123ABC%#$' to target station ID = 8F via relay station IDs = 01, 02, 03, and get ACK from the target station. The source station Equipment ID = 5F.

- Source station 5F status
  Control command: @DT 0A 0123ABC%#$ /A 01,02,03,8F CRLF or @DT 0A 0123ABC%#$ /A CRLF
  Control response: *DT = 0A CRLF
  ACK response from the target station: *DR = 00 CRLF          (issued after the relay time has elapsed)

- Target station 8F status
  Receive response: When RI = OF          *DR = 0A 0123ABC%#$ CRLF
                              When RI = ON          *DR = 0A 0123ABC%#$ /R 5F,01,02,03 CRLF

■ **6.4.1.2 @DT...% control transmit command**

The control transmit command 'DT...%' is a command that the user can use freely for system control. The format of this command assumes the relay function, but with 1:1 communication, set the route information with just one target station. Received signal level information for the packet is always included at the front of the receive response of the target station in response to a control transmit command. This command can also be used for data transmission, but it is easier to write a program if you distinguish this command from data transmit commands.

There is also a method of notation where the control transmit command makes the target station return data receive acknowledgement (ACK).

**1. Receive confirmation acknowledgement: no ACK**

With this command, control is transmitted using the relay function.

Format 1: '@' + 'DT' + control size + control + '%R' + route information + 'CRLF'
Format 2: '@' + 'DT' + control size + control + '%R' + 'CRLF'

Details
   Format '@DT ss DD….D %R rr,rr,...,rr 'CRLF'
   ss: Shows the control size in 2 hexadecimal digits and ASCII characters Value: 00h to FFh, maximum 255 bytes
   DD…D:      D expresses 1-byte data. Value: 00h to FFh, amount of data: maximum 255 bytes
   rr,rr,…,rr:   Shows the route information in 2 hexadecimal digits and ASCII characters Value: 00h to FEh, number of relay stations maximum 10 units

• With Format 1, the route information is entered directly in the command.
• With Format 2, transmission is based on route information set in the route register with the RT command. When entering the route information, enter the Equipment ID of the target unit at the end. With 1:1 communication, set only one Equipment ID for the target station in the route information. If no route information is set (NA set for the RT command), the equipment set as the Destination ID will be the target station.
• To output the same control from all currently connected relay stations, issue the command with '%S' instead of '%R'.

   Example: Transmit the 10-byte (0Ah) control '0123ABC$#4' to target station ID = 8F via relay station IDs = 01, 02, 03. The source station Equipment ID = 5F.

• Source station 5F status
   Transmit command: @DT 0A 0123ABC$#4 %R 01,02,03,8F CRLF or @DT 0A 0123ABC$#4 %R CRLF

   Transmit response: *DT = 0A CRLF

• Target station 8F output
   When RI = OF
   *DC = 45 0A 0123ABC$#4 CRLF
   When RI = ON
   *DC = 45 0A 0123ABC$#4 /R 5F,01,02,03 CRLF

* '45h' at the front indicates the signal level of the received packet. In this case, it is -69 dBm (45h).
For details of the value, refer to the 'RA' command.
* When RI = ON, the delimiter character is '/', not '%'.

## 2. Receive confirmation acknowledgement: with ACK

With this command, control is transmitted using the relay function, but it is possible to get control receive confirmation acknowledgement (ACK) from the target station.

Format 1: '@' + 'DT' + control size + control + '%A' + route information + 'CRLF'
Format 2: '@' + 'DT' + control size + control + '%A' + 'CRLF'

Details
    Format '@DT' ss DD….D '%A' rr,rr,…,rr 'CRLF'
    ss: Shows the control size in 2 hexadecimal digits and ASCII characters Value: 00h to FFh, maximum 255 bytes
    DD…D:    D expresses 1-byte data. Value: 00h to FFh, amount of data: maximum 255 bytes
    rr,rr,…,rr:    Shows the route information in 2 hexadecimal digits and ASCII characters Value: 00h to FEh, number of relay stations maximum 10 units

- With Format 1, the route information is entered directly in the command.
- With Format 2, transmission is based on route information set in the route register with the RT command. When entering the route information, enter the Equipment ID of the target unit at the end. With 1:1 communication, set only one Equipment ID for the target station in the route information. If no route information is set (NA set for the RT command), the equipment set as the Destination ID will be the target station.
- To output the same data from all currently connected relay stations, issue the command with '%B' instead of '%A'.

Example: Transmit the 10-byte (0Ah) control '0123ABC$#4' to target station ID = 8F via relay stations ID = 01, 02, 03. The source station Equipment ID = 5F.

- Input to source station 5F
  Transmit command: @DT 0A 0123ABC$#4 %A 01,02,03,8F CRLF or @DT 0A 0123ABC$#4 %A CRLF
  Transmit response: *DT = 0A CRLF0

- Target station 8F output
  When RI = OF
  *DC = 45 0A 0123ABC$#4 CRLF
  WHEN RI = ON
  *DC = 45 0A 0123ABC$#4 /R 5F,01,02,03 CRLF

*'45h' at the front indicates the signal level of the received packet. In this case, it is -69 dBm (45h).
For details of the value, refer to the 'RA' command.
*When RI = ON, the delimiter character is '/', not '%'.

■ **6.4.2 Receive response**

• **Response basic format**

Prefix + response name + '=' + value 1 + value 2 + data (control) + option response + terminator (= 'CRLF')

Prefix: '*' = 2Ah, a code that indicates the start of the response string.
Response name: The 2 ASCII characters 'DR'.
Value 1: 1 byte hexadecimal value to show the RSSI information. Specified by 2 ASCII characters.
Value 2: 1 byte hexadecimal value to show the size of the user data. Specified by 2 ASCII characters.
Data: Byte sequence of user data.
(Control): A byte data string that can be used freely for system control.
Option response: Route information and the like.
Terminator: A code that indicates the end of the command 'CRLF' (0Dh, 0Ah).


Receive response example
Response character string                   Hexadecimal code actually returned from the MU-1
*DR = 06 abc123 CRLF                        2A,44,52,3D,30,36,61,62,63,31,32,33,0D,0A


■ **6.4.2.1 *DR data receive response**
When the MU-1 receives user data normally, the received data is output following the '*DR' response. The front of the data shows the size of the received data. There is no value 1.
The receive response option responses (/R, /S, /A, /B) correspond to the command options of the transmit commands.


Example: Receives 20-byte user data (14h) '012345ABCD@$#CIRCUIT'

Source station = 11, relay stations = 22, 33, target station = 44


Transmit command without ACK: @DT 14 012345ABCD@$#CIRCUIT /R 22,33,44 CRLF

Receive response:

When RI is OF                    *DR = 14 012345ABCD@$#CIRCUIT CRLF
When RI is ON                    *DR = 14 012345ABCD@$#CIRCUIT /R 11,22,33 CRLF


Transmit command with ACK: @DT 14 012345ABCD@$#CIRCUIT /A 22,33,44 CRLF

Receive response:

When RI is OF                    *DR = 14 012345ABCD@$#CIRCUIT CRLF
When RI is ON                    *DR = 14 012345ABCD@$#CIRCUIT /R 11,22,33 CRLF


The following are cases with relay station output
Transmit command without ACK: @DT 14 012345ABCD@$#CIRCUIT /S 22,33,44 CRLF

Receive response:

When RI is OF                    *DR = 14 012345ABCD@$#CIRCUIT CRLF
When RI is ON                    *DR = 14 012345ABCD@$#CIRCUIT /R 11,22,33 CRLF


Transmit command with ACK: @DT 14 012345ABCD@$#CIRCUIT /B 22,33,44 CRLF

Receive response:

When RI is OF                    *DR = 14 012345ABCD@$#CIRCUIT CRLF
When RI is ON                    *DR = 14 012345ABCD@$#CIRCUIT /R 11,22,33 CRLF

■   **6.4.2.2 *DC control receive response**

When the MU-1 receives controls normally, the received control is output following the '*DC' response. The front of the data shows the received signal level of the received packet. Next is the control size. The receive response option responses (/R, /S, /A, /B) correspond to the command options of the transmit commands.

Example: Receives 20-byte user data (14h) '012345ABCD@$#CIRCUIT'

Source station = 88, relay stations = 99, AA, target station = BB

In this case, the received signal level is -69 dBm (45h).

Transmit command without ACK: @DT 14 012345ABCD@$#CIRCUIT %R 99,AA,BB CʀLꜰ

Receive response:

|  |  |
|---|---|
| When RI is OF | *DC = 45 14 012345ABCD@$#CIRCUIT CʀLꜰ |
| When RI is ON | *DC = 45 14 012345ABCD@$#CIRCUIT /R 88,99,AA CʀLꜰ *01 |

Transmit command with ACK: @DT 14 012345ABCD@$#CIRCUIT %A 99,AA,BB CʀLꜰ

Receive response:

|  |  |
|---|---|
| When RI is OF | *DC = 45 14 012345ABCD@$#CIRCUIT CʀLꜰ |
| When RI is ON | *DC = 45 14 012345ABCD@$#CIRCUIT /R 88,99,AA CʀLꜰ *01 |

* 01: Note that the '%' for transmit commands is '/' for responses.

■   **6.4.2.3 *DS data receive response with RSSI information**

When the MU-1 receives user data normally, the received data is output following the '*DS' response, and the received signal level information (RSSI) of the received data packet is also output with it. The RSSI level information is attached to the front of the data, followed by the data size and the data.
In order to enable the receive response, set the attach RSSI information mode to ON with the @SI command. With OF, the response is *DR.
The receive response option responses (/R, /S, /A, /B) correspond to the command options of the transmit commands.

Example: Receives 20-byte user data (14h) '012345ABCD@$#CIRCUIT'

Source station = 44, relay stations = 55, 66, target station = 77

When the received signal level is -85 dBm (55h).

Transmit command without ACK: @DT 14 012345ABCD@$#CIRCUIT /R 55,66,77 CʀLꜰ

Receive response:

|  |  |
|---|---|
| When RI is OF and SI is OF | *DR = 14 012345ABCD@$#CIRCUIT CʀLꜰ |
| When RI is OF and SI is ON | *DS = 55 14 012345ABCD@$#CIRCUIT CʀLꜰ |
| When RI is ON and SI is OF | *DR = 14 012345ABCD@$#CIRCUIT /R 44,55,66 CʀLꜰ |
| When RI is ON and SI is ON | *DS = 55 14 012345ABCD@$#CIRCUIT /R 44,55,66 CʀLꜰ |

Transmit command with ACK: @DT 14 012345ABCD@$#CIRCUIT /A 55,66,77 CʀLꜰ

Receive response:

|  |  |
|---|---|
| When RI is OF and SI is OF | *DR = 14 012345ABCD@$#CIRCUIT CʀLꜰ |
| When RI is OF and SI is ON | *DS = 55 14 012345ABCD@$#CIRCUIT CʀLꜰ |
| When RI is ON and SI is OF | *DR = 14 012345ABCD@$#CIRCUIT /R 44,55,66 CʀLꜰ |
| When RI is ON and SI is ON | *DS = 55 14 012345ABCD@$#CIRCUIT /R 44,55,66 CʀLꜰ |

* SI = Attach RSSI information mode, RI = Attach route information mode

■  **6.4.2.4 ACK response**

The ACK response is a signal that shows that the data transmit command or control transmit command reached the target station without any errors. ACK is not returned from the relay stations. In addition, route information is not attached to ACK responses. If the attach RF received signal level mode is set to ON, RSSI information is attached to the ACK response.

The receive responses in response to commands with ACK are as follows.

**1. With data transmit commands with ACK**

Example: The appearance of the source station ACK response when the 10-byte (0AH) data 'PPPPPPPPPP' is transmitted with the data transmit command. Following the characters 'DR' or 'DS', the received signal level and '00' indicating the ACK response are output.

Source station = 44, relay stations = 55, 66, target station = 77

When the target station received signal level is -85 dBm (55h), and the source station ACK receive level is -89 dBm (59h).

• **When the mode setting with RF received signal level information SI is OF**

Source station output ()

@<u>DT</u> <u>0A</u> <u>PPPPPPPPPP</u> /A <u>55,66,77</u> CʀLꜰ      ← Data transmit command

*<u>DT</u> = <u>0A</u> CʀLꜰ                          ← Transmit response

*<u>DR</u> = <u>00</u> CʀLꜰ                          ← ACK response (no RSSI information)

Target station output

*<u>DR</u> = <u>55</u> <u>0A</u> <u>PPPPPPPPPP</u> /R <u>44,55,66</u> CʀLꜰ  ← Receive response (data)

• **When the mode setting with RF received signal level information SI is ON**

Source station output ()

@<u>DT</u> <u>0A</u> <u>PPPPPPPPPP</u> /A <u>55,66,77</u> CʀLꜰ      ← Data transmit command

*<u>DT</u> = <u>0A</u> CʀLꜰ                          ← Transmit response

*<u>DS</u> = <u>59</u> <u>00</u> CʀLꜰ                       ← ACK response (with RSSI information)

Target station output

*<u>DR</u> = <u>55</u> <u>0A</u> <u>PPPPPPPPPP</u> /R <u>44,55,66</u> CʀLꜰ  ← Receive response (data)

**2. With control transmit commands with ACK**

Example: The appearance of the source station ACK response when the 10-byte (0AH) data 'PPPPPPPPPP' is transmitted with the control transmit command. Following the characters 'DC', the received signal level and '00' indicating the ACK response are output.

Source station = 44, relay stations = 55, 66, target station = 77

When the target station received signal level is -85 dBm (55h), and the source station ACK receive level is -89 dBm (59h).

Source station output

@<u>DT</u> <u>0A</u> <u>PPPPPPPPPP</u> <u>%A</u> <u>55,66,77</u> CʀLꜰ      ← Control transmit command

*<u>DT</u> = <u>0A</u> CʀLꜰ                          ← Transmit response

*<u>DC</u> = <u>59</u> <u>00</u> CʀLꜰ                       ← ACK response

Target station output

*<u>DC</u> = <u>55</u> <u>0A</u> <u>PPPPPPPPPP</u> /R <u>44,55,66</u> CʀLꜰ  ← Receive response (control)

■ **6.4.3 Control commands and control responses**

• **Command format**

Prefix + command name + value + terminator (= 'C<sub>R</sub>L<sub>F</sub>')

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
@CH 1F C<sub>R</sub>L<sub>F</sub>                          40,43,48,31,46,0D,0A

・ **Response format**

Prefix + command name + '=' + value + terminator (= 'C<sub>R</sub>L<sub>F</sub>')

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 = 1F C<sub>R</sub>L<sub>F</sub>                          2A,43,48,3D,31,46,0D,0A

| | Note | 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. |
| --- | --- | --- |

■ **6.4.3.1 @BR   UART baud rate setting**

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: @BR 57 CRLF                  Response from the MU-1: *BR = 57 CRLF


■ **6.4.3.2 @CH   Frequency channel setting**

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

Default: 07h

Value: 00h - 3Fh (hexadecimal value that indicates channels 0 to 64)

Example: Change the channel to 15 (0Fh)
    Control command: @CH 0F CRLF
    Control response:
        When RM = CD     *CH = 0F CRLF
        When RM = TX     *CH = 0F : 433.575MHz CRLF


■ **6.4.3.3 @CT   Test data transmission**

Transmits test data. Specify 'ON' to transmit data continuously, specify a count value when transmitting for a specified time, and specify 'OF' to stop transmission. The transmission data is the 'CRLF' sent repeatedly, and the receive response of the target station is '*DR = 00'. If there is any input data during transmission, the data is transmitted.

Default: 'OF'

Value: 'ON': Continuous transmission on, 'OF': Continuous transmission off, Count value: ASCII code that expresses 01h to FFh

The count value is 10 seconds per count. The maximum value is FFh, 2,550 seconds.

Example 1: Continuous data transmission on
    Control command: @CT ON CRLF                Control response: *CT = ON CRLF

Example 2: Continuous data transmission off
    Control command: @CT OF CRLF       Control response: *CT = OF CRLF

Example 3: Transmit data for 60 seconds
    Control command: @CT 06 CRLF       Control response: *CT = ON CRLF

■ **6.4.3.4 @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.

Do not use commands with ACK responses (command options: /A, /B, %A, and %B) with the broadcast function when using the relay function.

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

Example: Change the Destination ID to 25h
    Command to the MU-1: @DI 25 CRLF          Response from the MU-1: *DI = 25 CRLF

■ **6.4.3.5 @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 '@RA' 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: @EI 34 CRLF          Response from the MU-1: *EI = 34 CRLF

■ **6.4.3.6 @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 – FFh
Example: Change the Group ID to 34h
    Command to the MU-1: @GI 34 CRLF          Response from the MU-1: *GI = 34 CRLF

■ **6.4.3.7 @IZ   Initialize**

Returns the MU-1 to the factory default values. The content of the EEPROM fixed with the '/W' option is also initialized.

After using this command, always execute the SR command.

Example:
    Control command: @IZ CRLF
    Control response: When RM = CD       *IZ = 00 CRLF
                 When RM = TX    *IZ = 00 : ROM was initialized. CRLF

■ **6.4.3.8 @MD   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: @MD TX CRLF          Response from the MU-1: *MD = TX CRLF

Example 2: Change to the binary mode
    Command to the MU-1: @MD BI CRLF          Response from the MU-1: *MD = BI CRLF

■ **6.4.3.9 @PB    UART parity bit setting**

   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: @PB EV CʀLꜰ          Response from the MU-1: *PB = EV CʀLꜰ

■ **6.4.3.10 @RI    Attach route information mode**
Specifies whether or not to include route information in the receive response ('*DR') at the target station.
To include route information, set to ON.

Default: OF
Value:                    ON: Attach route information                    OF: No route information
Example 1: Attach route information mode setting
Control command: @RI ON CʀLꜰ          Control response: *RI = ON CʀLꜰ

Example 2: DR response
      When RI is ON                *DR = 03 ABC /R 20,01,02,03 CʀLꜰ
      When RI is OF                *DR = 03 ABC CʀLꜰ

■ **6.4.3.11 @RM    Response display mode**
Sets the method of displaying the content of 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: @RM CD CʀLꜰ          Response from the MU-1: *RM = CD CʀLꜰ

■ **6.4.3.12 @RR    Receive route information use setting**
Writes the route information of the received data packet in the route register, and sets whether or not to use it as return route information. If a data transmit command (control transmit command) transmitted in accordance with the content of the route register is issued at the target station, the data is sent automatically towards the source station. However, note that the route information set with the route setting command is overwritten each time a data packet is received. This operation is only enabled when a transmit command is received from the source station.

Default: OF
Value:                ON: Receive route information used    OF: Receive route information setting not used
Example: Turn on use of receive route information
   Control command: @RR ON CʀLꜰ                Control response: *RR = ON CʀLꜰ

■   **6.4.3.13 @RT   Relay route designation**
Sets the route information in the route register. Setting is possible up to a maximum of 10 relay stations. When entering the route information, enter the Equipment IDs (EI) of the relay stations in the order of the relay. Specify the Equipment ID (EI) of the target station at the end. For details of data transmission using relay stations, refer to the DT command.

Default: All 00h
Value: (00h – FEh),......,(00h-FE)   A maximum number of 10 units can be specified
Example: Set route information for transmitting 'ABC' from the source station with Equipment ID = 5F via relay station IDs 01, 02 and 03 to target station Equipment ID = 8F.

    Control command: @RT 01,02,03,8F C<sub>R</sub>L<sub>F</sub>
    Control response: *RT = 01,02,03,8F C<sub>R</sub>L<sub>F</sub>

☞   Hint: When only one Equipment ID is entered in the RT command, that becomes the direct target station. In other words, the operation is the same as when the DI is set.

■   **6.4.3.14 @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: @SB 01 C<sub>R</sub>L<sub>F</sub>                Response from the MU-1:   *SB = 01 C<sub>R</sub>L<sub>F</sub>

■   **6.4.3.15 @SI   Mode setting with RF received signal level information**
Sets whether or not to output the RF received signal level information (RSSI) at the source station with the data when the packet data is received. To include the information, set the mode to ON. The information is attached to the front of the receive response ('*DS'). With OF, the response is DR.

Default:   OF
Value                ON:   Attach RSSI information                OF:   No RSSI information

Example 1: Attach RSSI information mode setting
Control command:        @SI ON C<sub>R</sub>L<sub>F</sub>                Control response:  *SI = ON C<sub>R</sub>L<sub>F</sub>

Example 2: Appearance of the DS response (when the RSSI is -85 dBm = 55 hex, RI is ON)
When SI is ON                *DS = 55 03 ABC /R 20,01,02,03 C<sub>R</sub>L<sub>F</sub>
When SI is OF                *DR = 03 ABC /R 20,01,02,03 C<sub>R</sub>L<sub>F</sub>

Example 3: Appearance of the DS response (when the RSSI is -70 dBm = 46 hex, RI is OF)
When SI is ON                *DS = 46 03 ABC C<sub>R</sub>L<sub>F</sub>
When SI is OF                *DR = 03 ABC C<sub>R</sub>L<sub>F</sub>

■   **6.4.3.16 @SN   Show serial number**
Shows the serial number of the MU-1. The serial number is the 9-digit control number shown on the label of the main unit. The response from the MU-1 is in ASCII characters.

    Example:
    Control command: @SN C<sub>R</sub>L<sub>F</sub>
    Control response: *SN = A12345678 C<sub>R</sub>L<sub>F</sub>

■   **6.4.3.17 @SR   Reset**
Returns the MU-1 to the status when the power is turned on. The MU-1 starts up with the fixed content of the EEPROM with the '/W' option.

    Example:
    Control command: @SR C<sub>R</sub>L<sub>F</sub>
    Control response:
        When RM = CD    *SR = 00 C<sub>R</sub>L<sub>F</sub>
        When RM = TX    *SR = 00 : Software reset was performed. C<sub>R</sub>L<sub>F</sub>

■   **6.4.3.18 @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: @TB 20 CʀLꜰ         Response from the MU-1: *TB = 20 CʀLꜰ

■   **6.4.3.19 @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 - FFh
Example: Set waiting time to 0Ah (10 × 1.024 = 10.24 s)
   Command to the MU-1: @TC 0A CʀLꜰ         Response from the MU-1: *TC = 0A CʀLꜰ

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

■   **6.4.3.20 @UI   User ID setting**

User IDs are IDs (about 30,000) 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 parameters derive 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.

A password is required for setting a User ID, but the passwords for the following 16 User IDs are publicly available so they can be used freely. The password follows the User ID in brackets.

**0000** (0B27), **EFF1** (4E74), **EFF2** (D18E), **EFF3** (5909), **EFF4**(82B5),
**EFF5** (9D47), **EFF6** (E4D1), **EFF7** (3B2F), **EFF8** (B3A6), **EFF9** (6C5A),
**EFFA** (C6F7), **EFFB** (7F6F), **EFFC** (15C4), **EFFD** (0A34), **EFFE** (F7E8), **EFFF** (A09C)

If you require a unique User ID and password, please contact Circuit Design, Inc. directly. Please ensure that you do not lose your User ID and password.

Default: 0000h
Value: 01h to FFh (FFh cannot be used)

Example: Set the User ID to 0000h with the password 0B27h provided.
Command to the MU-1: @UI 0000,0B27 CʀLꜰ
Response from the MU-1: *UI = 0000 CʀLꜰ

* 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.

■   **6.4.3.21 @VR   Display program version**

Obtains the program version of the MU-1.
Example:
   Command to the MU-1: @VR CʀLꜰ
   Response from the MU-1: *VR = 11 Ver1.1 2003/08/29 15:00 CʀLꜰ

■ **6.4.4 Test command and test response**

• **Command basic format**

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

Prefix: '@'=40h, a code that indicates the start of the command string.
Command name: The 2 ASCII characters. 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
@CP 06 abc123 /01,02,03 C$_R$L$_F$

Hexadecimal code actually sent to the MU-1
40,43,50,30,36,61,62,63,31,32,33,2F,30,31,2C,30,32,2C,30,33,2C,0D,0A

• **Response basic 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 'CP'.
Value: The size of data received with the 'CP' command.

Response example
*CP = 06 C$_R$L$_F$                06h (6) bytes received

■    **6.4.4.1 @CA    Target station all channel RSSI absolute level measurement**

The RSSI (Received Signal Strength Intensity) of the specified target station is measured over all channels. It is possible to check the floor noise level of the field, third party field strength, and noise level of the system itself. The RSSI value is the received strength of the radio waves inducted through the antenna of the target station. The measured value is output as a 2-digit hexadecimal number in ASCII characters that expresses the absolute value for RSSI. The code of the RSSI value acquired is minus.

> Format 1: '@' + 'CA' + '/' + route information + 'CRLF'
> Format 2: '@' + 'CA' + 'CRLF'
>
> Details
>   Format1: '@CA' '/' rr,rr,...,rr 'CRLF'
>   Format2: '@CA' '/' 'CRLF'
>   rr,rr,…,rr: Shows the route information in 2 hexadecimal digits and ASCII characters Value: 00h to FEh, number
>       of relay stations maximum 10 units

- With Format 1, the route information is entered directly in the command.
- With Format 2, transmission is based on route information set in the route register with the RT command or on the content of the Destination ID. When entering the route information, enter the Equipment ID of the target unit at the end. If no route information is set (NA set for the RT command), the equipment set as the Destination ID will be the target station.
- It is possible to make the source station the target. In this case, after entering one or more relay stations, enter the Equipment ID of the source station at the end.


Example: The RSSI of target equipment number 8F is measured over all channels. The relay stations are 01, 02, and 03.
- Source station status
  Test command: @CA / 01,02,03,8F CRLF or @CA CRLF
  Test response: *CA = 00 CRLF
  Receive response with regard to the data transmitted from the target station:
            *DR = 80 7C7D....7E7D CRLF
  A response for 64 channels of RSSI is returned as 128-byte (80 hex) ASCII characters (code is minus)

- Target station status
  There is no response.

■　**6.4.4.2 @CP　Packet test**

Transmits data for packet testing.
　　Transmits data packets to the specified target unit, and the target unit returns the data without change. Any packet length of 1 to 255 bytes can be specified.

　　Format 1: '@' + 'CP' + data size + data + '/' + route information + 'C$_{RLF}$'
　　Format 2: '@' + 'CP' + data size + data + 'C$_{RLF}$'

　　Details
Format1: '@CP' ss DD….D '/A' rr,rr,...,rr 'C$_{RLF}$'
Format2: '@CP' ss DD….D '/A' 'C$_{RLF}$'
　　ss: Shows the data size in 2 hexadecimal digits and ASCII characters Value: 00h to FFh, maximum 255 bytes
　　DD…D: D expresses 1-byte data. Value: 00h to FFh, amount of data: maximum 255 bytes
　　rr,rr,…,rr: Shows the route information in 2 hexadecimal digits and ASCII characters Value: 00h to FEh, number of relay stations maximum 10 units

• 　With Format 1, the route information is entered directly in the command.
• 　With Format 2, transmission is based on route information set in the route register with the RT command or on the content of the Destination ID. When entering the route information, enter the Equipment ID of the target unit at the end. If no route information is set (NA set for the RT command), the equipment set as the Destination ID will be the target station.

Example: Transmit 'ABC' from the source station with Equipment ID = 5F via relay station IDs 01, 02 and 03 to target station Equipment ID = 8F, and the data is returned without change.
• 　Source station status
　　Test command: @CP 03 ABC / 01,02,03,8F C$_{RLF}$ or @CP 03 ABC C$_{RLF}$
　　Test response: *CP = 03 C$_{RLF}$
　　Receive response with regard to the data transmitted from the target station:
　　　　　　　　*DR = 03 ABC C$_{RLF}$

• 　Target station status
　　There is no response.

■ **6.4.4.3 @CR   Target station RSSI absolute level measurement**

Measures the RSSI (Received Signal Strength Intensity) of the specified target station. The RSSI value is the received signal strength of the target station. In addition, the floor noise level of the field where the target station is located can also be acquired. The measured value is output as a 2-digit hexadecimal number in ASCII characters that expresses the absolute value for RSSI. The code of the RSSI value acquired is minus.

Format 1: '@' + 'CR' + '/' + route information + 'CRLF'
Format 2: '@' + 'CR' + 'CRLF'

Details
Format1: '@CR' '/' rr,rr,...,rr 'CRLF'
Format2: '@CR' '/' CRLF'
rr,rr,…,rr: Shows the route information in 2 hexadecimal digits and ASCII characters Value: 00h to FEh, number
        of relay stations maximum 10 units

- With Format 1, the route information is entered directly in the command.
- With Format 2, transmission is based on route information set in the route register with the RT command or on the content of the Destination ID. When entering the route information, enter the Equipment ID of the target unit at the end. If no route information is set (NA set for the RT command), the equipment set as the Destination ID will be the target station.
- It is possible to make the source unit the target. In this case, after entering one or more relay stations, enter the Equipment ID of the source unit at the end.

Example: Measure the RSSI of target equipment number 8F. The relay stations are 01, 02, and 03.
- Source station status
  Test command: @CR / 01,02,03,8F CRLF or @CR CRLF
  Test response: *CR = 00 CRLF
  Receive response with regard to the data transmitted from the target station:
      When RM = CD    *DR = 04 55 80 CRLF                    *55h = 85, 80h = 128
      When RM = TX    *DR = 14 CRLF
                      S –85dBm N –128dBm CRLF

- Target station status
  There is no response.

■   **6.4.4.4 @RA   RSSI absolute value measurement**

Measures the absolute value for Received Signal Strength Intensity (RSSI) of the channel set. The measured value is a hexadecimal value that indicates the RSSI absolute value.
Range of the hexadecimal value that indicates the RSSI absolute value: 00h to FFh
The code of the RSSI value acquired is minus.

   Format 1: '@' + 'RA' + 'CRLF'

 Example: Measure the RSSI absolute value of the current channel

   Test command: @RA CRLF

   Test response:

        When RM = CD    *RA = 63 CRLF              *63h = 99
        When RM = TX    *RA = 63 –99dBm CRLF


■   **6.4.4.5 @RC   All channel RSSI absolute level measurement**

Measures the RSSI (Received Signal Strength Intensity) over all channels. It is possible to check the floor noise level of the field, third party field level, and field level of the system itself. The measured value is output as a 2-digit hexadecimal number in ASCII characters that expresses the absolute value for RSSI. The code of the RSSI value acquired is minus.

   Format 1: '@' + 'RC' + 'CRLF'

 Example: Measure the RSSI absolute value over all channels.
   Test command: @RC
   Test response: *RC = 7A7C7D....7E7D CRLF
   A response is returned for 64 channels of RSSI data (128-byte ASCII characters)
   The code is minus. 7A = -122dBm

■ **6.4.5 Extended command and extended response**

■ **6.4.5.1 @DTxx@CHxx/C   Change the target station channel**

Changes the channel used by the specified target station. Start changing the channels of the equipment located furthest away.

> Format 1: '@' + 'DT05' + '@CH' + channel number + '/C' + route information + 'CʀLꜰ'
> Format 2: '@' + 'DT05' + '@CH' + channel number + '/C' + 'CʀLꜰ'
> Format 3: '@' + 'DT07' + '@CH' + channel number + '/W' + '/C' + route information + 'CʀLꜰ'
> Format 4: '@' + 'DT07' + '@CH' + channel number + '/W' + '/C' + 'CʀLꜰ'
>
> Details
> Format 1: '@DT05' '@CH' cc '/C' rr,rr,...,rr 'CʀLꜰ'
> Format 2: '@DT05' '@CH' cc '/C' 'CʀLꜰ'
> Format 3: '@DT07' '@CH' cc '/W' '/C' rr,rr,...,rr 'CʀLꜰ'
> Format 4: '@DT07' '@CH' cc '/W' '/C CʀLꜰ'
>   cc: Enter the channel number in 2 hexadecimal digits and ASCII characters   Value: 00h to 3Fh
>   rr,rr,…,rr:     Shows the route information in 2 hexadecimal digits and ASCII characters Value: 00h to FEh,
>     number of relay stations maximum 10 units

- With Format 1,3, the route information is entered directly in the command.
- With Format 2,4, transmission is based on route information set in the route register with the RT command or on the content of the Destination ID. When entering the route information, enter the Equipment ID of the target unit at the end. If no route information is set (NA set for the RT command), the equipment set as the Destination ID will be the target station.
- Formats 3 and 4: To fix the changed channel in the EEPROM, attach the '/W' option.

Example: Change the channel of the target station equipment number = 8F to 46ch (2E) channel. The relay stations are 01, 02, and 03.
- Source station status
  Extended command: @DT 05 @CH2E /C 01,02,03,8F CʀLꜰ or @DT 05 @CH2E /C CʀLꜰ
  Extended response: *DT = 05 CʀLꜰ
  Receive response with regard to the data transmitted from the target station:
    *DR = 05 @CH2E CʀLꜰ

- Target station status
  There is no response.

■    **6.4.5.2 @DTxx@CHxx/F Changing channels of multiple stations at once**

Changes the channels used by multiple specified target stations at once. It is possible to change the channels of the stations and source station entered in the route information at once. The timing by which the channels of the stations are changed is the moment when, after the target stations receive the change channel command from the source station, the ACK responses are received by the various stations. Stations that cannot confirm the ACK signal due to an error remain in their original channel. In this case, investigate the channel range of the system, and change the channels with the target station channel changing command, starting with the most distant stations.

     Format 1: '@' + 'DT05' + '@CH' + channel number + '/F' + route information + 'C$_{R}$L$_{F}$'
     Format 2: '@' + 'DT05' + '@CH' + channel number + '/F' + 'C$_{R}$L$_{F}$'
     Format 3: '@' + 'DT07' + '@CH' + channel number + '/W' + '/F' + route information + 'C$_{R}$L$_{F}$'
     Format 4: '@' + 'DT07' + '@CH' + channel number + '/W' + '/F' + 'C$_{R}$L$_{F}$'

     Details
     Format 1: '@DT05' '@CH' cc '/F' rr,rr,...,rr 'C$_{R}$L$_{F}$'
     Format 2: '@DT05' '@CH' cc '/F' 'C$_{R}$L$_{F}$'
     Format 3: '@DT07' '@CH' cc '/W' '/F' rr,rr,...,rr 'C$_{R}$L$_{F}$'
     Format 4: '@DT07' '@CH' cc '/W' '/F' 'C$_{R}$L$_{F}$'
      cc: Enter the channel number in 2 hexadecimal digits and ASCII characters    Value: 00h to 3Fh
      rr,rr,…,rr:      Shows the route information in 2 hexadecimal digits and ASCII characters Value: 00h to FEh,
       number of relay stations maximum 10 units

•    With Format 1,3, the route information is entered directly in the command.
•    With Format 2,4 transmission is based on route information set in the route register with the RT command or on the content of the Destination ID. When entering the route information, enter the Equipment ID of the target unit at the end. If no route information is set (NA set for the RT command), the equipment set as the Destination ID will be the target station.
•    Formats 3 and 4: To fix the changed channel in the EEPROM, attach the '/W' option.

Example: Change the channel of the target station equipment number = 8F to 46ch (2E) channel. The relay stations are 01, 02, and 03.
•    Source station status
     Extended command: @DT 05 @CH2E /F 01,02,03,8F C$_{R}$L$_{F}$ or @DT 05 @CH2E /F C$_{R}$L$_{F}$
     Extended response: *DT = 05 C$_{R}$L$_{F}$
     Command response: *CH = 2E C$_{R}$L$_{F}$

•    Target station status
     There is no response.

■　**6.4.5.3 @DT05@CTxx/C　Issue target station test data**

Issues link test data from the specified target station for the time specified with the count value.
The transmission data is the 'CRLF' sent repeatedly, and the receive response of the receiving station is '*DR=00'. If there is any input data during transmission, the data is transmitted.

　　Value: Count value: ASCII code that expresses 01h to FFh

- The count value is 10 seconds per count. The maximum value is FFh, 2,550 seconds.

　　Format 1: '@' + 'DT05' + '@CT' + count value + '/C' + route information + 'CRLF'
　　Format 2: '@' + 'DT05' + '@CT' + count value + '/C' + 'CRLF'

　　Details
　　Format 1: '@DT05' '@CT' xx '/C' rr,rr,...,rr 'CRLF'
　　Format 2: '@DT05' '@CT' xx '/C' 'CRLF'
　　　xx:　Value
　　　rr,rr,…,rr:　　　Shows the route information in 2 hexadecimal digits and ASCII characters Value: 00h to FEh, number of relay stations maximum 10 units

- With Format 1, the route information is entered directly in the command.
- With Format 2, transmission is based on route information set in the route register with the RT command or on the content of the Destination ID. When entering the route information, enter the Equipment ID of the target unit at the end. If no route information is set (NA set for the RT command), the equipment set as the Destination ID will be the target station.

Example: Issue a test signal for 60 seconds from the target station equipment number = 8F. The relay stations are 01, 02, and 03.
- Source station status
　　Extended command: @DT 05 @CT06 /C 01,02,03,8F CRLF or @DT 05 @CT06 /C CRLF
　　Extended response: *DT = 05 CRLF
　　Receive response with regard to the data transmitted from the target station:
　　　　　　　　*DR = 05 @CT06 CRLF

- Target station status
　　There is no response.

■ **6.4.5.4 @DT03@SR/C    Reset the target station**

Resets the specified target stations. Resetting means returning the MU-1 to the status when the power was turned on. The user starts it up with fixed settings in the EEPROM.

Format 1: '@' + 'DT03' + '@SR' + '/C' + route information + 'C$_{RLF}$'
Format 2: '@' + 'DT03' + '@SR' + '/C' + 'C$_{RLF}$'

Details
Format 1 '@DT03' '@SR' '/C' rr,rr,...,rr 'C$_{RLF}$'
Format 2 '@DT03' '@SR' '/C' C$_{RLF}$'
    rr,rr,…,rr:        Shows the route information in 2 hexadecimal digits and ASCII characters Value: 00h to FEh,
        number of relay stations maximum 10 units

- With Format 1, the route information is entered directly in the command.
- With Format 2, transmission is based on route information set in the route register with the RT command or on the content of the Destination ID. When entering the route information, enter the Equipment ID of the target unit at the end. If no route information is set (NA set for the RT command), the equipment set as the Destination ID will be the target station.

Example: Reset the target station equipment number = 8F. Relay stations 01, 02, and 03.
- Source station status
    Extended command: @DT 03 @SR /C 01,02,03,8F C$_{RLF}$ or @DT 03 @SR /C C$_{RLF}$
    Extended response: *DT = 03 C$_{RLF}$
    Receive response with regard to the data transmitted from the target station:
                    *DR = 03 @SR C$_{RLF}$

- Target station status
    There is no response.

■ **6.4.5.5 @DT03@SR/F Resetting multiple stations at once**

Resets the specified stations. Resetting means returning the MU-1 to the status when the power was turned on. The user starts it up with fixed settings in the EEPROM.

It is possible to reset the stations and source station entered in the route information. The timing by which the stations are reset is the moment when, after the target stations receive the reset command from the source station, the ACK responses are received by the various stations. Stations that cannot confirm the ACK signal due to an error are not reset.

Format 1: '@' + 'DT03' + '@SR' + '/F' + route information + 'CRLF'
Format 2: '@' + 'DT03' + '@SR' + '/F' + 'CRLF'

Details
Format 1 '@DT03' '@SR' '/F' rr,rr,...,rr 'CRLF'
 rr,rr,…,rr:  Shows the route information in 2 hexadecimal digits and ASCII characters Value: 00h to FEh, number of relay stations maximum 10 units

• With Format 1, the route information is entered directly in the command.
• With Format 2, transmission is based on route information set in the route register with the RT command or on the content of the Destination ID. When entering the route information, enter the Equipment ID of the target unit at the end. If no route information is set (NA set for the RT command), the equipment set as the Destination ID will be the target station.

Example: Reset the target station equipment number = 8F, relay stations 01, 02, 03, and the source station.
• Source station status
 Extended command: @DT 03 @SR /F 01,02,03,8F CRLF or @DT 03 @SR /F CRLF
 Extended response: *DT = 03 CRLF
 Command response: *SR = 00 CRLF

• Target station status
 There is no response.

■ **6.4.6 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.

• **Format**

Prefix + response name + '=' + value + terminator (= 'CRLF')

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

Example error response
Response character string                    Hexadecimal code actually returned from the MU-1
*ER = 1D CRLF                     2A,45,52,3D,31,44,0D,0A

Example: Error response when the '@BR' command is issued
1. When the command '@RM = CD ' is issued
        *ER = 0A CRLF

2. When the command '@RM = TX ' is issued
        *ER = 0A : BR command format error CRLF

| 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 | RA command format error | The 'RA' 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 2-digit Hex character for the 'DI' command |
| 0E | DI command format error | The 'DI' command format is wrong |
| 0F | EI command error | Use a 2-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 |
| 1E | RT command format error | The 'RT' command format is wrong |
| 1F | IZ command format error | The 'IZ' command format is wrong |
| 20 | SR command format error | The 'SR' command format is wrong |
| 21 | RI command format error | The 'RI' command format is wrong |
| 22 | SN command format error | The 'SN' command format is wrong |
| 23 | - | |
| 24 | - | |
| 25 | RC command format error | The 'RC' command format is wrong |
| 26 | SI command format error | The 'SI' command format is wrong |
| 27 | RR command format error | The 'RR' command format is wrong |
| 28 | - | |
| 29 | RA command format error | The 'RA' command format is wrong |

Caution: The error codes for the CA, CP, and CR commands are the DT command errors 05 and 06.

# Chapter 7   Timing

## >> General command & response timing
## (excluding the @CH, @RA commands)

Issue command
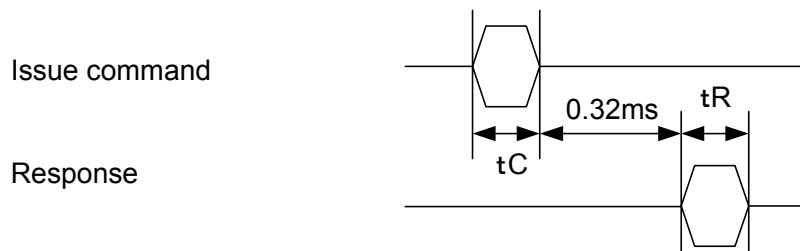
Response

$$tC = A \times 10000 / br \qquad tR = B \times 10000 / br$$

A = Command length
A=7: GI,EI,DI,CH,BR,PB,SB,MD,TC,TB,CT,RI,RM,SY,SI,RR
A=5: VR,SN,SR,IZ,RA,RC
A=14: UI
A=Number of relay station x 3 + 7: RT
A=Number of relay station x 3 + 8: CA,CR

B = Response length
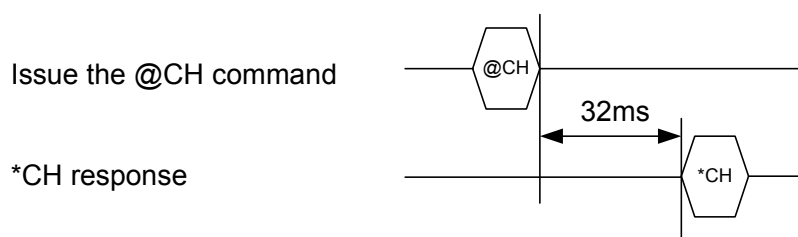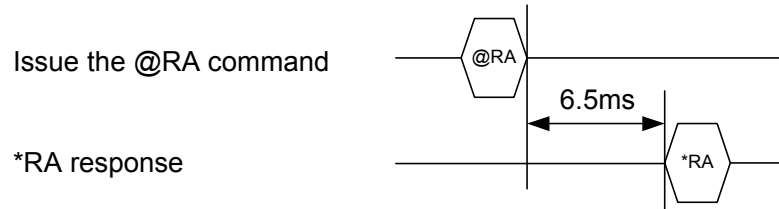B=8:GI,EI,DI,CH,BR,PB,SB,MD,TC,TB,CT,RI,RM,SR,IZ,SI,RR,RA,CA
,CR,CP
B=10: UI
B=0: SY
B=15: SN
B=Number of relay stations x 3 + 8: RT

## >> CH command & response timing

Issue the @CH command

*CH response

## >> RA command & response timing

Issue the @RA command

@RA

6.5ms

*RA response

*RA

## >> Command & response timing
## when /w option is specified

Issue command with /w

55ms
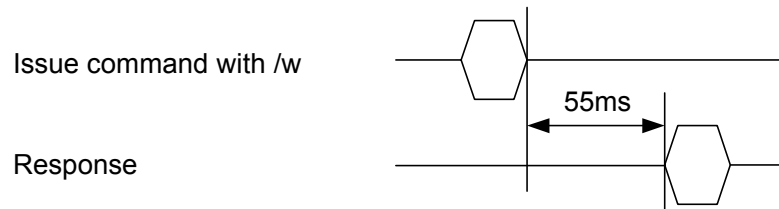
Response

* 87 ms when @CH/w (written in the EEPROM)

## >> Transmit command time
## (data and control transmit commands)

Source station
data transmit command
@DT

@DT

tC

200 $\mu$ s

Transmit response
*DT

*DT

tR
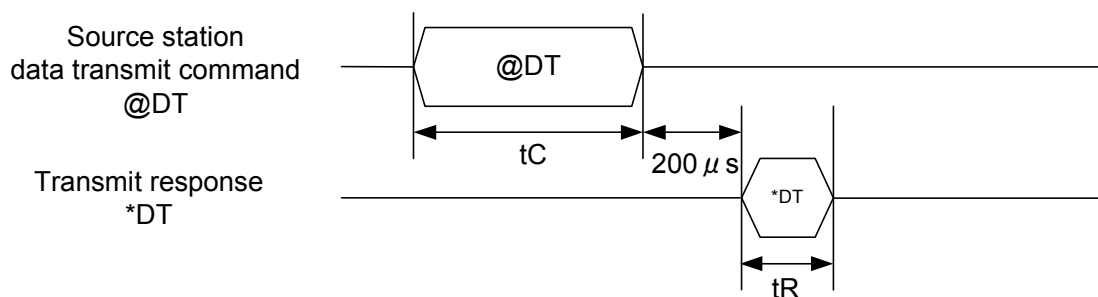
Command time tC = N x 10000 / br

Transmit response time tR = 8 x 10000 / br

* Units are ms, br = UART bit rate, N = n + o + r + 7,
n = Number of data bytes sent (within 255 bytes), o = Number of command option characters
(/A, %R etc.), r = Number of route information characters = Number of relay stations x 3 + 2

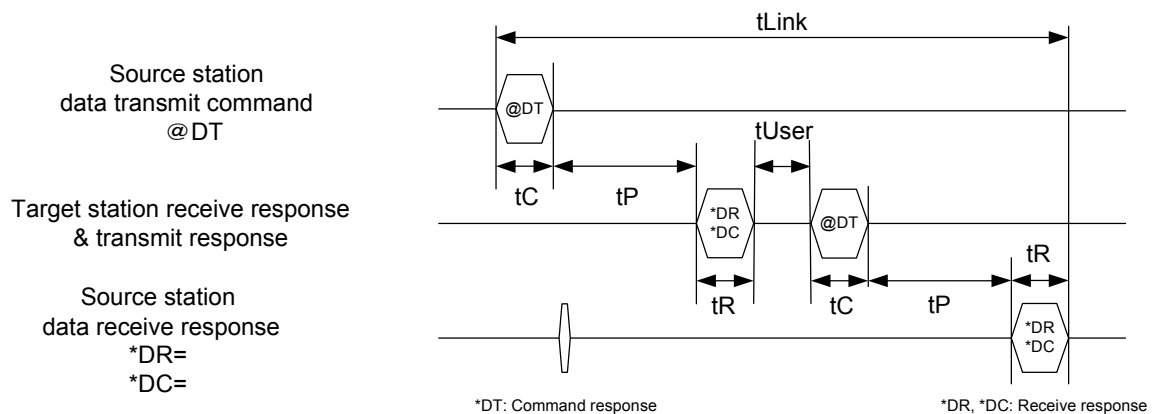## >> Period when issuing commands is prohibited when turning on power



Power ON

Power supply (VCC)

MU-1 operation

Commands can be issued

100ms

Period when commands is prohibited
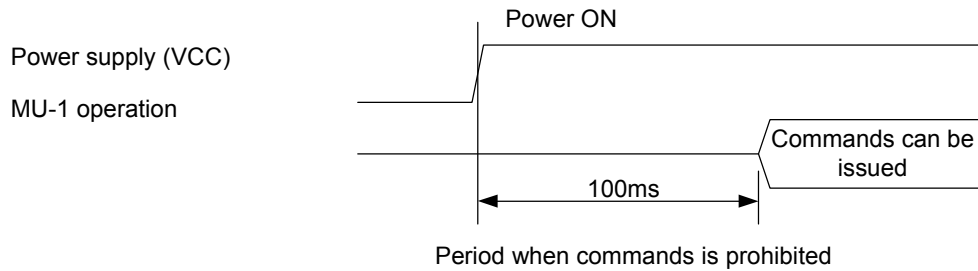
## >> Transmit and receive time (no relay function, when 1 frame is transmitted)

Source station data transmit command
@DT

Target station receive processing



@DT

tC    tP

*DR
*DC

tR

*DT: Command response
*DR, *DC: Receive response

Command time tC = (n + 7) x 10000 / br

Response time tR = (n + 8) x 10000 / br

Radio transmission time tP = (n x 1.04) + 34
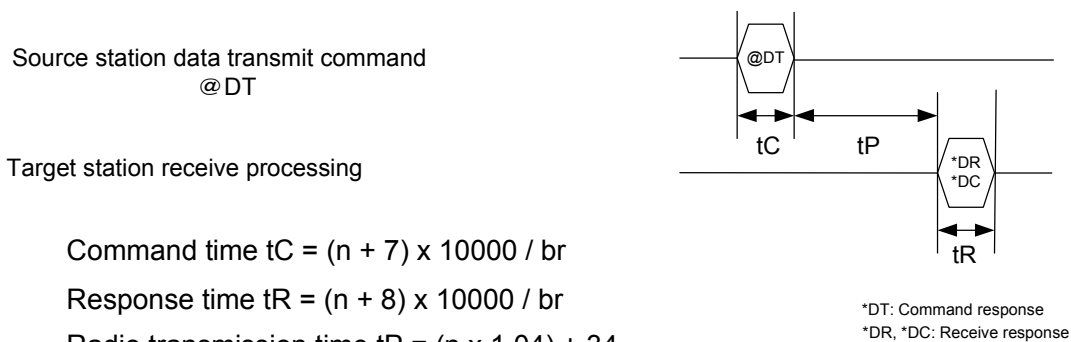
* Units are ms, n = Number of data bytes sent (within 255 bytes), br = UART bit rate

## >> Time to establish link (no relay function, when 1 frame is transmitted)



tLink

Source station
data transmit command
@DT

Target station receive response
& transmit response

Source station
data receive response
*DR=
*DC=

tC    tP

tUser

*DR
*DC

@DT

tR

tR    tC    tP

*DR
*DC

*DT: Command response

*DR, *DC: Receive response

Command time tC = (n + 7) x 10000 / br          Radio transmission time tP = (n x 1.04) + 34

Response time tR = (n + 8) x 10000 / br

tUser = User program processing time          tLink = Time to establish link

* Units are ms, n = Number of data bytes sent (within 255 bytes), br = UART bit rate
* Reference value with 20-byte link data: tLink = 129 ms   Conditions: 57,600bps, without entering tUser

## >> Relay function timing (with ACK, when 1 frame is transmitted)
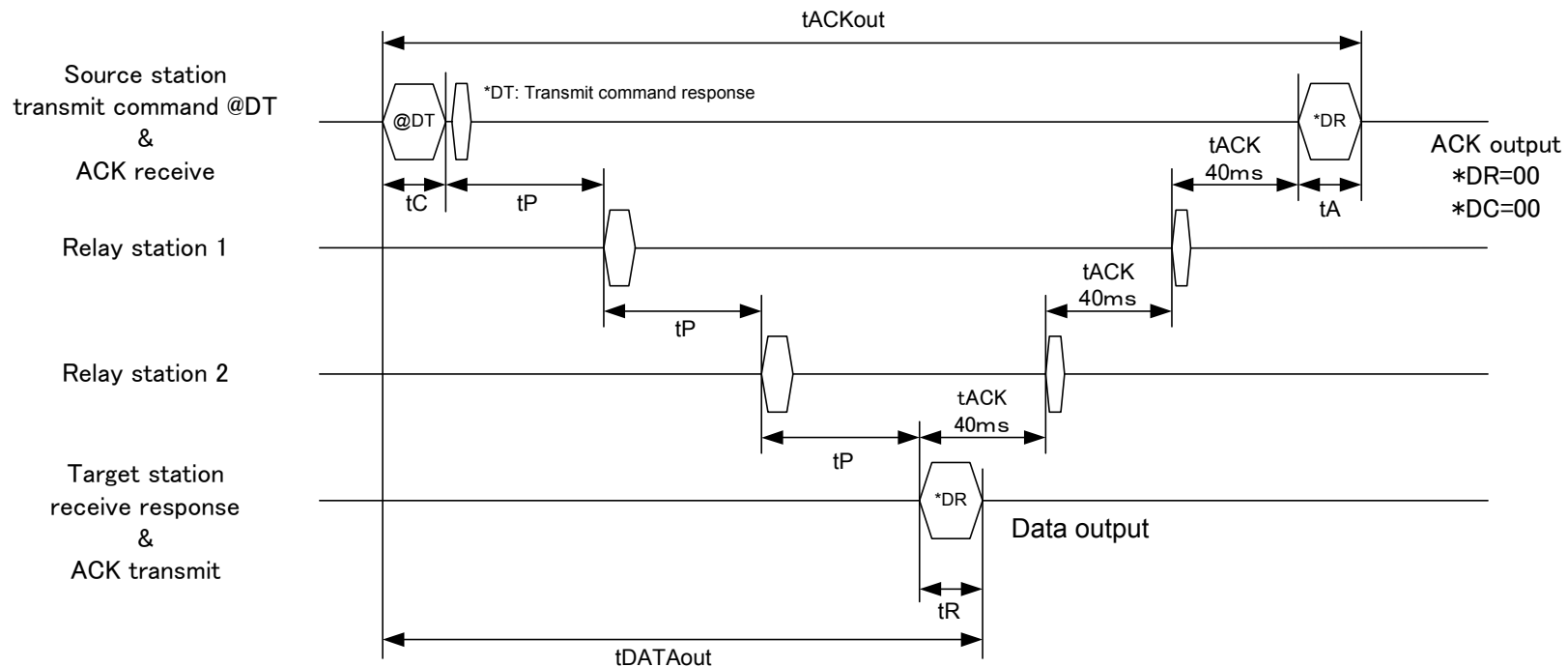


$$tDATAout = tC + tP \cdot (m + 1) + tR$$

$$tACKout = tC + (m + 1)(40 + tP) + tA$$

Command time $tC = (n + 7) \times 10000 / br$

Radio transmission time $tP = (n \times 1.04) + 38.2 + (m \times 1.04)$

Receive response time $tR = (n + 8) \times 10000 / br$

ACK response time $tA = 80000 / br$

* Units are ms, n = Number of data bytes sent (within 255 bytes), br = UART bit rate, m = Number of relays(up to 10 units)
* Reference value With 20-byte link data: $tDATAout = 262$ ms, $tACKout = 378$ ms
  Conditions: 57,600bps, 2 relays
* Data output time when there is no ACK response is calculated with tDATAout
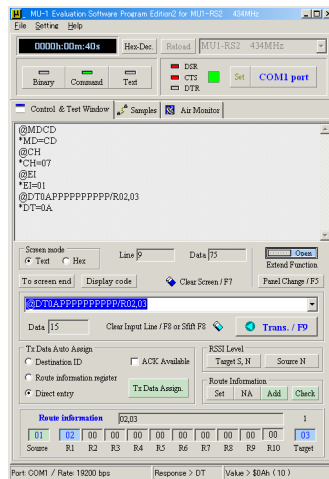
# Chapter 8 Miscellaneous

## 8.1 The MU-1 Evaluation Program

It is convenient to use the dedicated Evaluation Program MU1-ESP for evaluating the MU-1.
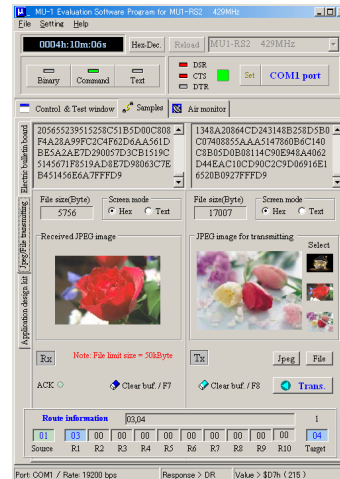
Refer to the MU1-ESP manual for details of the evaluation method. The Evaluation Program comes with the various interface kits that use the MU-1. For details, please visit the Circuit Design website.

You can issue all the commands from the command window. You can also check the performance of the MU-1 with a communication test where an image is transmitted using one-way communication. Using the air monitor, you can check the field status of the equipment you design. (It is necessary to design your product so that it can be connected to a PC with the RS232C interface.)
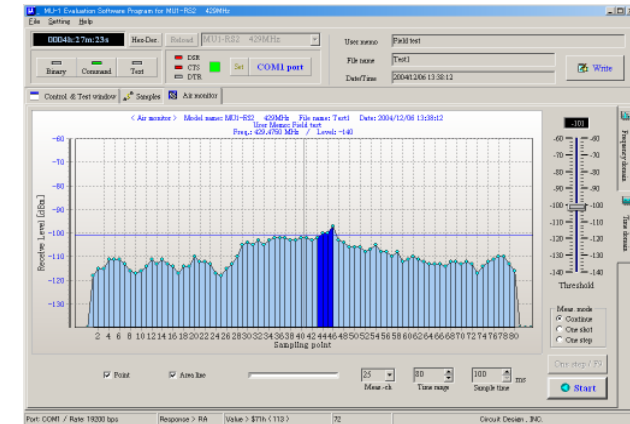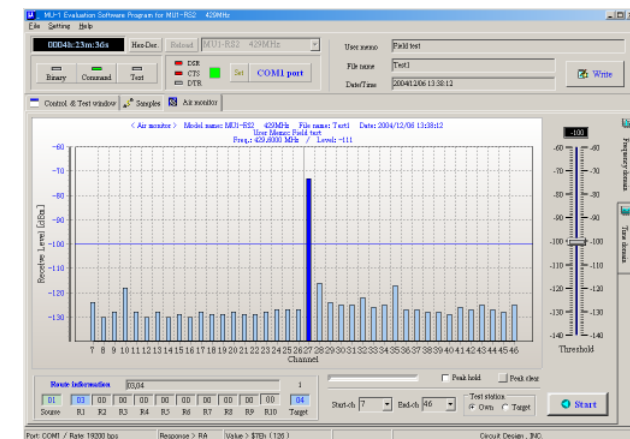
◆ Air monitor (frequency domain)



◆ Command window



JPEG image transmission test



◆ Air monitor (time domain)

## 8.2 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.

◆ **Preparation**

Before starting the evaluation, turn on the power while pressing the Initialize button 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 Initialize button initializes all of the MU-1 parameters, so do not press it for any other reason than initialization.
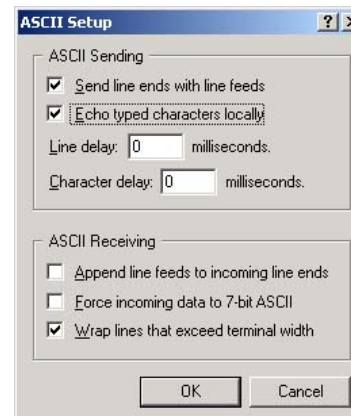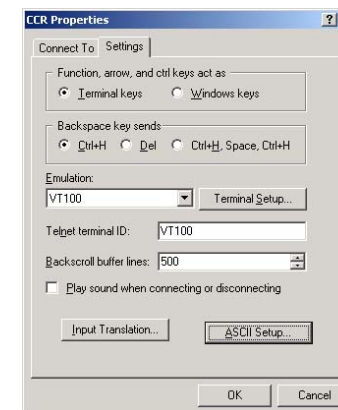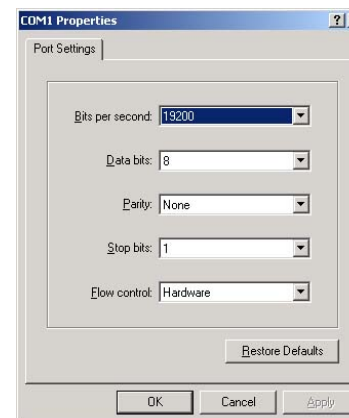
◆ **Evaluation**

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.

◆ **Settings**

◆ **Note**

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 9 Regulatory Compliance

## 9.1 Regulatory Compliance of the MU-1

■ **9.1.1 Regulatory compliance of the MU-1**

The MU-1 is made for embedding in other equipment.
(Products incorporating the MU-1 are henceforward referred to as final products.)
The European regulation applicable 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 the health and the safety | EN60950, EN 50371 |
| Articles 3.1(b) | EMC | EN 301 489 |
| Articles 3.2 | Effective use of the spectrum | EN 300 220 |

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

Note: The MU-1-R is intended to be used in all EU and EFTA countries.
There may be restrictions on the use of voice and audio applications in the following countries; FI, FR, HU, IT, LU, LI, CH.

■ **9.1.2 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 final product in which the MU-1 is used must be designed so that the frequency band and duty cycle conform to the radio regulations of the countries where it is to be used.

The MU-1 is designed to be used in the frequency bands **f** and **f2** in the ERC/REC 70-03 (Edition of October 2005) Annex 1, Non-Specific Short Range Devices shown in the table below and from 433.050 to 434.790 MHz. Specifically, the MU-1 is channelized in 25 kHz steps and has channels 0 to 63 in the 433.050 to 434.790 MHz band. (Refer to the table in 2.3 Usable Channels). The nominal RF output of the MU-1 is fixed at 10 mW.

Table 1

| | Frequency Band | Power | Channel Spacing | Duty Cycle (%)* |
|---|---|---|---|---|
| **f** | 433.050-434.790 Hz | 10 mW e.r.p. | No channel spacing | Below 10% |
| **f1** | 433.050-434.790 Hz | 1 mW e.r.p., -13 dBm/10 kHz for wide band channels | No channel spacing | No duty cycle restriction |
| **f2** | 434.040-434.790 Hz | 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.

Frequency band **f** in Annex 1 above is harmonized. Based on the R&TTE Directive, radio equipment that has these frequencies and technical characteristics can be introduced on the market without restriction within the EC as Class 1 radio equipment. Radio equipment that meets the criteria outside of **f** for frequencies and technical characteristics that are not harmonized is defined as Class 2 radio equipment, and there are still some countries that implement restrictions on its sale and use. When using Class 2 radio equipment, it is necessary to notify the radio regulatory authority in the country where it will be used, and to attach a class identifier (alert symbol) stating that there are countries that limit the use of the product.

Specifically if the final product equipped with the MU-1 is operated within 433.050 to 434.790 MHz with a duty cycle of 10% or less, the final product is classified as Class 1 radio equipment.

Otherwise, if for example the final product uses the MU-1 at a duty cycle higher than 10%, it is classified as Class 2 radio equipment, the radio regulatory authority must be notified, and the product must be labeled with an alert symbol.

By frequency channel used

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

(2) When using the MU-1 at duty cycles higher 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 show 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 |
| f | 433.050-434.790 MHz | 0 to 63 | 433.200 to 434.755 MHz | 25 kHz |
| f2 | 434.040-434.790 MHz | 34 to 63 | 434.050 to 434.755 MHz | 25 kHz |

Remarks: This information is valid as of May 2008.

## 2. Antenna

The radio and EMC parameters of the MU-1 radio modem 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 radio modem cannot be used for the conformity assessment of the final product.

## 3. Supply voltage

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

## 4. Enclosure

To fulfill the requirements of EMC and safety requirements, the MU-1 should be mounted on the circuit board of the final product and must be enclosed in the case of the final product. No surface of the MU-1 should be exposed.

## 5. Documentation

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

## 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.

## 9.2 Declaration of Conformity

# DECLARATION OF CONFORMITY

## Directive 99/5/EC (R&TTED)

We, Circuit Design, Inc of 7557-1 Hotaka, Azumino-city, Nagano 399-8303, Japan declare under our sole responsibility that the products

Radio modem      MU-1-R

To which this declaration relates, are in conformity with the following standards and/or other normative documents.

EN 300 220-2, V2.4.1      Receiver category 2
EN 301 489-3 V1.6.1
EN 60950-1
EN 62479

We hereby declare that all essential radio test suites have been carried out and that the above named products are in conformity to all the essential requirement of Directive 1999/5/EC.

Technical documents relevant to the above equipments can be made available for inspection on application to:

Circuit Design, Inc.
7557-1 Hotaka, Azumino-city, Nagano 399-8303, Japan

Nagano Japan   Sep. 10, 2015
Place and date of issue

Masayasu Komiyama,
Executive General manager, Engineering Div.

## Important notice

- Customers are advised to consult with Circuit Design sales representatives before ordering.
  Circuit Design believes the provided information is accurate and reliable. However, Circuit Design reserves the right to make changes to this product without notice.

- Circuit Design products are neither designed nor intended for use in life support applications where malfunction can reasonably be expected to result in significant personal injury to the user. Any use of Circuit Design products in such safety-critical applications is understood to be fully at the risk of the customer and the customer must fully indemnify Circuit Design, Inc for any damages resulting from any improper use.
- As the radio module communicates using electronic radio waves, there are cases where transmission will be temporarily cut off due to the surrounding environment and method of usage. The manufacturer is exempt from all responsibility relating to resulting harm to personnel or equipment and other secondary damage.
- The manufacturer is exempt from all responsibility relating to secondary damage resulting from the op eration, performance and reliability of equipment connected to the radio module.

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## Cautions

- Do not use the equipment within the vicinity of devices that may malfunction as a result of electronic radio waves from 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 soot 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 a part 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.

## REVISION HISTORY

| Version | Date | Description | Remark |
|---------|------|-------------|--------|
| 1.0 | Jul. 2006 | MU-1-R 434MHz     The first issue | |
| 1.1 | May 2008 | Some minor corrections, addition of note (P73) and DOC update (P74). | P.73, 74 and others |
| 1.2 | Aug. 2013 | DOC updated | |
| 1.3 | Feb. 2014 | DOC updated | |
| 1.4 | Sep.2015 | DOC updated | |
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