How to use FRnet

1. What is FRnet?

FRnet is a two-wire serial communication bus, wired in a similar manner to an RS-485. FRnet device connection is achieved using a multi-drop method. Unlike most communication methods based on RS-485, this new method does not use the traditional question/answer approach. Instead, it uses a fixed scan time to actively transmit data. Since there is no need for a CPU to process a communication protocol, FRnet can achieve high-speed data transmission in an isochronous manner.

When FRnet is adopted as the I/O interface in an embedded controller, control of I/O data can be easily achieved by reading/writing to the memory (memory-mapped I/O), making the development of application programs very simple, which not only saves a great deal of time in communication protocol processing, but also guarantees the isochronous properties. Therefore, FRnet is highly suitable for applications that require remotely controlled, high-speed data transmission, and allows for major savings when wiring.

2. How does FRnet work?

Two types of nodes exist in FRnet **–** **SENDER** and **RECEIVER**. The node number of the sender is called the Sender Address, or **SA**. The node number of the receiver is called the Receiver Address, or **RA**. A sender can simultaneously transmit data to many different receivers via FRnet bus lines if they have identical node numbers. Therefore, nodes that have identical number can be called a **Group**. For example, if device A has an SA node number set as n, and another device, named B, has its RA node number also set as n, then device A will send data to device B through the FRnet.

In order to achieve a fixed scan time, the total number of groups must be assigned in advance, and each group must have a unique number. ICP DAS provides two types of products that use a different number of groups. One type allows for 16 groups (-016), and the other provides up to 128 groups (-128).

FRnet transmits data by using differential signals on two physical lines. In order to avoid data collision, each group is activated using a time-slicing method. Time-slicing is controlled by a Sync Manager, located on the SA0 node, which cyclically sends a token to activate each group. When a group is activated, data is sent from the SA node to the RA nodes. To avoid data collision, the SA node must be unique. In this way, data refresh is performed one group at a time. Therefore, the refresh time (or scan time) is related to the number of groups.

Each SA node can send 16-bit data and each RA node can receive 16-bit data during each scan time. For each group, only a single SA node exists, while it can have many RA nodes. Therefore, one device can send the same data or message to many nodes at the same time. This is called 1-vs-n transmission, or broadcast capability. When compared to traditional question/answer communication methods, this feature enables FRnet products to accomplish facility expansion without changing any control programs, such as a seat-scalable 4D Theater design. If the broadcast feature is ignored, the two-wire FRnet can still provide 256 bits (for 16-group products) or 2048 bits (for 128-group products) data transmission.

FRnet does not require a CPU to process the data communication. Specially designed communication chips are used to ensure the data integrity under operational conditions. When communication quality is insufficient, warning LEDs on the modules will illuminate to notify the user of the communication problem.

3. Does FRnet have a fixed scan time (cycle time)?

FRnet allows for two communication speeds. The first is 1Mbps (high speed mode, or the H version), and the second is 250Kbps (low speed mode, or the L version). If the model number of the module does not include a suffix, the default is the L version. Sometimes the L version is called the "normal-speed" version, because its speed is not actually slow. In addition, the number of groups (16 or 128) affects the scan time.

Depending on the transmission speed and the number of groups, the scan time can be calculated as follows:

Number of groups	Speed	Cycle time
16	1Mbps	0.72 ms
16	250Kbps	2.88 ms
128	1Mbps	5.76 ms
128	250Kbps	23.04 ms (not available at this time)

The number and designation of groups must be defined in advance, and are as follows:

Number of groups	Available Group Numbers
16	0, 1, 2, .. , 15
128	0, 1, 2, .. , 126, 127

Other group numbers and transmission speeds are not available at this time.

The number of groups that are defined and the transmission speed determines the cycle time of the FRnet. Once determined, it will not change no matter how many devices are used. The timing deterministic control loops enable us to analyze and anticipate the control performance.

4. How far can data be transmitted on an FRnet bus?

By using general communication wires (CPEV-S 0.9), the following transmission distances can be easily achieved.

Transmission Speed	Transmission Distance
1Mbps	100m
250Kbps	400m

5. How much data can be transferred on an FRnet system?

Basically, each group can process 16-bit data. If a system has 16 groups, it will transfer 256 bits of data per cycle time. If a system has 128 groups, it can transfer 2,048 bits per cycle time. The feature allowing 1-vs-n transmission (duplicated RA nodes), enables FRnet to theoretically extend its control points almost without limit. However, each SA node must be unique, meaning, therefore, that the available DI points are limited.

Generally speaking, the FRnet system can be planned as DO only, DI only, or partially DI and partially DO points. Since the majority of systems need both DI and DO, ICP DAS provides controllers with defined SA and RA nodes that share all available groups equally. The I-7188EF-016, for example, includes 8 SA nodes and 8 RA nodes that are located in 16 individual groups. Therefore, the I-7188EF-016 FRnet controller can be used to simultaneously remotely control 128 DO and 128 DI points. PCI-bus FRB series cards also have equal numbers of SA nodes and RA nodes.

In contrast to the controllers, the remote DI/DO modules are designed to include a limited number of nodes, but with adjustable node addresses. For example, the FR-2053 is a 16-bit DI module that only has a single SA node. From the communication aspect or FRnet principles, it is apparent DI modules must have SA nodes while DO modules have RA nodes.

6. How to design a system based on the FRnet?

To successfully design a system based on FRnet communication principles, following basic ideas should be kept in mind.

(a) Data transmission occurs inside a group, not between groups. (A group is composed of nodes that have identical SA and RA values)
(b) The direction of data transmission is from SA to RA
(c) Each group may **not** have more than one SA node. The SA node must be unique
(d) Each group may have many RA nodes. Therefore, RA nodes may have duplicates
(e) A Sync Manager, which is located on the SA0 node, controls the number of groups to be activated. Therefore, an SA0 node must exist on the bus
(f) Since the transmission line is common among all modules, the transmission speed settings for each module must be the same (1Mbps or 250Kbps).

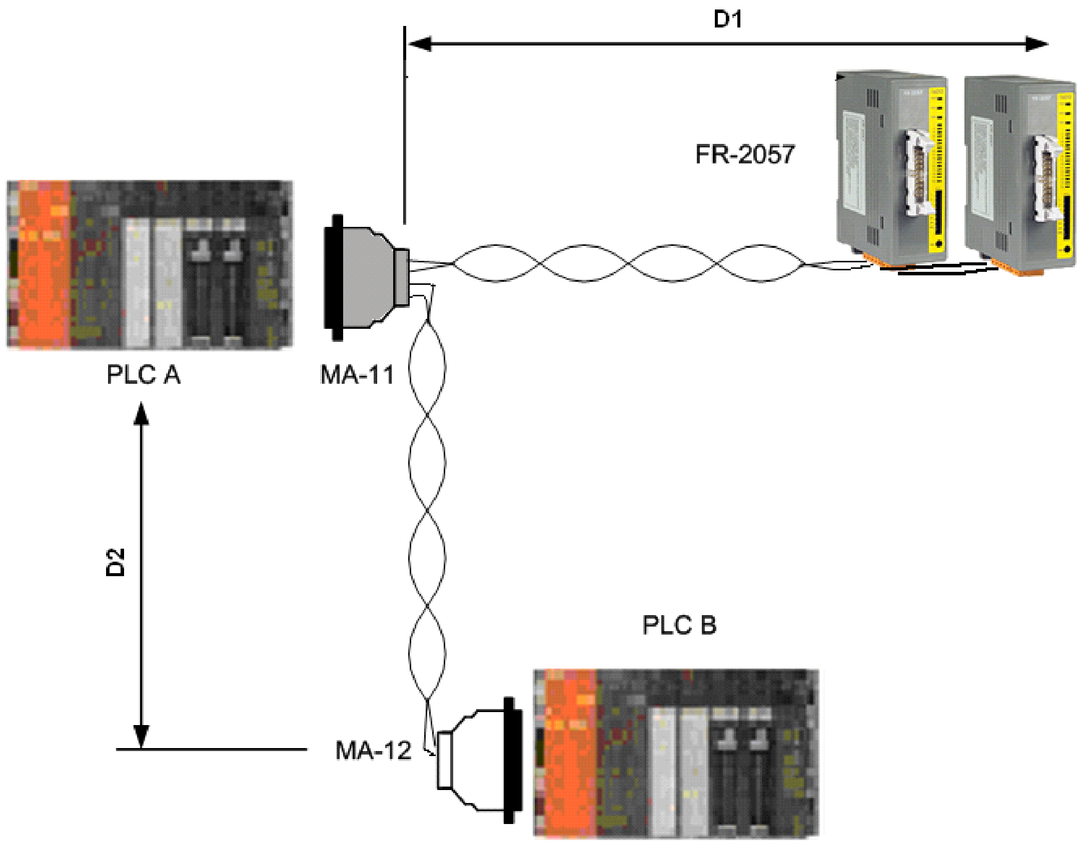
The next step is to consider how to use FRnet products to construct a system for control or communication. The definition of a group provides the concept for the data flow (from SA to RA). First, consider the data flow direction, and then choose suitable products to construct the system. For example, say that there are two PLCs, called A and B, that need high-speed data transmission. If the amount data to be exchanged is not great, connecting the DO module of PLC A to the DI module of PLC B is the most direct solution. However, if the distance between the two PLCs is great, not only is the wiring difficult and expensive, but the voltage could drop and external noise could cause communication to become unreliable. A network of communication modules is an alternative solution in this situation. However, such a network is expensive and, sometimes, difficult to purchase. In such situations, MagicWire products are possibly the best solution, as the parallel bus can be replaced with an FRnet serial bus.

For example, in the following diagram, PLC A is performing a remote 32 DO control function, using MagicWire (MA-11) to link to two remote FR-2057 DO modules. If there is a monitoring PLC (B) that needs to retrieve the control status of PLC A, another MagicWire product (MA-12) can provide a solution by connecting the MA-12 to the DI of PLC B, and dropping the twisted wires onto the FRnet bus. If the RA number is set to be the same as the SA number of PLC A, then PLC B can acquire the data transmited by PLC A to the FR-2057 module.

The steps to be taken, in detail, are:

(1) Set the SA nodes of the MA-11 to be SA0 and SA1
(2) Set the RA nodes of the two FR-2057 modules to be RA0 and RA1
(3) Set the RA nodes of the MA-12 to be RA0 and RA1, then the remote control and monitoring system is established.

This system demonstrates how FRnet enables the PLC to extend its DI/DO at a distance, and how the monitoring is achieved via FRnet. Although it is easy to construct such systems, there is one thing that must be paid attention to. The distance, (D1+D2), must be less than 400m when the transmission speed is 250Kbps, or less than 100m if the speed is set to 1Mbps.



7. **Is a CPU required for processing the communication of FRnet?**

FRnet does not require a CPU to deal with communication issues. For example, MagicWire series products perform data transmission without using a CPU. Both the MA-11 and MA-12 are MagicWire products. The MA-11H has two SA nodes, and the MA-12H has two RA nodes. Communication is established by setting the SA and RA nodes as (SA0, SA1) and (RA0, RA1), respectively, then by connecting each module using a pair of twisted wires and by providing a power source for each module. The MA-11 continually sends 32-point data to the MA-12 once the connections and settings are initialized. By following the basic principles mentioned above, FRnet communication can be easily established.

Other settings and construction using MagicWire products are discussed below:

Case *1:* Suppose the MA-11H nodes are set as SA3 and SA4. Since the Sync Manager, which is located on SA0, does not exist, the FRnet cannot work. In this case, the red LED will be illuminated to indicate the error.

Case *2:* Suppose the nodes for MA-11H are set as SA0 and SA1, but the nodes of MA-12H are set as RA3 and RA4. Since these nodes belong to different groups, data transmission will not occur, even though the communication status indicated on the LED is shown to be okay.

Case *3:* Suppose the nodes for MA-11H are set as SA0 and SA1, but an MA-12L, rather than the MA-12H, is used as the corresponding receiver. Since the communication speed settings are different between MA-11H and MA-12L, the FRnet does not work. In this case, the red LED will illuminate to indicate this error.

Case *4:* Suppose there is an MA-11H and an MA-12H, and they are correctly connected. Suppose another two modules, an MA-11H and an MA-12H, are added to this system. One of the MA-11H modules must set be to (SA0, SA1). The other MA -11H must be set to have other node addresses, such as (SA2, SA3). The MA-12H that was added can use any node address. If it is set as (RA0, RA1), a 1-vs-2 broadcast transmission is formed. However, in this case, the second MA-11H module is wasted. If the nodes for MA-12H are set as (RA2, RA3), then a 64-bit data transmission link can be constructed.

When MagicWire is used to link the output or input modules, a CPU is still not necessary. However, any CPU that cooperates with FRnet is very easy to operate. FRnet uses a memory-mapped type I/O, so the CPU only needs to read/write memory to perform DI/DO control and takes almost no CPU processing time. Programming is also very easy.

Conventional communication methods require communication protocols, similar to the way information is requested from somebody using the normal mail. The address must be written on the envelope first and the message is contained in the envelope. After being processed at the mail office, the mailman delivers it to the receiver. The receiver reads the message after the letter is opened. Before a response letter is mailed, an inquiry letter must be sent.

TV broadcast system	FRnet system
Number of channels	Number of groups
Signals transmitted by stations	Data transmitted by SA nodes
Signal receivers (TV sets)	RA nodes

The FRnet systems perform data transmission in a similar manner to watching a television program. The number of available TV channels is limited. There are about 180 channels, but not every channel has a TV program available. The channels are similar to the FRnet group concept. Different programs are provided on different TV channels by a number of television stations. Every station transmits its own TV programs on a specific channel, similar to certain groups with SA nodes. Each channel can provide only one program at a time. This characteristic is similar to the uniqueness of the SA node. Each TV receives a different program according to signal transmitted by the different TV stations. We can tune our television set to another channel to watch a different program. This action is the same as altering the number of the RA node to receive data from a different SA node in the same way that the tuner of the TV set deals with the signal transmission issue. This approach is very similar to the built-in hardware used in an FRnet interface.

However, the TV broadcast system is a little different from the FRnet system. Different TV sets can receive different programs at the same time; however, the RA nodes in an FRnet system can receive data only when the corresponding group is activated. FRnet data transmission is performed via a time-slicing method.

8. When compared to RS-485, what are the advantages of FRnet?

Both FRnet and RS-485 are two-wire serial bus systems. Both adopt a multi-drop method to establish entire systems. However, FRnet data transmission is very fast, and does not need a CPU to process a communication protocol. Therefore, it may be applied in many places where an RS-485 cannot be used, such as directly linking PLCs.

If a system is constructed using RS-485 type modules, certain test programs must be run to test whether the connection is okay or not. In contrast, checking whether the settings and connections in an FRnet system are correct can be performed while wiring the system. In addition, there are a number of kit sets with dip switches and LEDs that can be used to debug the wiring of the system.

An RS-485 system must have a CPU on both the host and remote sites to perform the communication using a question/answer approach. The communication time taken using RS-485 and FRnet on an I-7188EF-016 module is compared in the following table.

Number of DI/DO Channels (bits)	DCOM (RS-485, 115.2Kbps)	FRnet (250Kbps)	FRnet (1Mbps)
16	1.30 ms	2.88 ms	0.72 ms
32	2.60 ms	2.88 ms	0.72 ms
64	3.90 ms	2.88 ms	0.72 ms
⋮	⋮	⋮	⋮
256	20.8 ms	2.88 ms	0.72 ms

In the table above, an RS-485 using the DCOM communication protocol was used to compare FRnet systems. Although the FRnet was not using its broadcast function, the table shows that FRnet is extremely efficient. However, since the RS-485 uses low speed transmission (115.2Kbps), the transmission distance can be longer, but it requires a program to process the communication protocol. In contrast, the FRnet does not require any programs to deal with the communication issue. Data is sent and acquired by the hardware. DI/DO control is performed by reading/writing to the corresponding I /O ports. The values 2.88ms and 0.72ms in this table only indicate the data refresh time, the actual I/O time is much less than these figures, while the time data shown in the RS-485 column are the measured values from experiments.

9. What are the benefits of FRnet?

A. It is a fast communication network that does not need any software programs to process the communication protocol.
B. It has broadcast capability.

C. The concept is simple. The usage is easy. The transmission speed is fast. The control distance is long. The control points are many.

D. It saves on wiring. Two twisted wires can replace 256 or 2,048 signal lines. There is not only savings in space and cost, but also the installation, debugging and maintenance of the system is easy.

E. I/O points are scanned by the hardware at fixed time intervals, so it is very useful for discrete time control.

F. Suitable arrangements of the SA and the RA nodes can achieve direct device communication.

G. When an error occurs, such as a broken bus line, the majority of output modules can retain the final DO states, which allows system operators to choose the most suitable method of processing the error situation, thereby reducing the loss.

H. FRnet data transmission is handled by the hardware. Specially designed circuits are provided in the hardware to prevent noise and disturbance. When a communication error occurs, the error LED will be illuminated. When the communication quality is drops below 70%, another warning LED will be illuminated. These LEDs provide very useful information for system debugging.

I. When using FRnet products, wiring becomes very easy. Therefore, hazards such as major power lines, where disturbance is most likely to come from, can be avoided when wiring network lines. In this way, system reliability can be further improved.

10. How many FRnet products are available at present?

ICP DAS Corporation has already developed the products shown at the following web site:

http://www.icpdas.com/products/frnet/frnet_index.htm.

These products can be classified into PC-based control cards (FRB series), embedded controllers (I-7188EF series), remote DI/DO modules (FR-2000 series and DNFR series), and the MagicWire (MA series). More products will available in the near future, including FRnet Learner Kits, AI/AO modules, FRnet on I-8000 modules, FRnet Hub, Switch, Repeater, and Sensor modules. Certain special products for long distance applications will soon be available as well.

11. What types of applications can FRnet be used for?

FRnet products are suitable to use with any application that requires many control points, minimum wiring, and cost and labor efficiency. Some examples are listed below.

- Communication between PLCs
- New LED control technology
- Automatic equipment and related systems
- Remote control
- Monitoring of debris flow and landslides
- Building Automation

    - Light control
    - Air-conditioning systems
    - Disaster warning and security systems
    - Power monitoring
- 4D theaters
- Parking lot management systems
- Automatic warehouse control systems
- Airport landing lamp control systems
- Post Office letter classification machine systems
- Fruit classification and packing systems
- Pneumatic or hydraulic valve control
- Elevator control