## Physical network and networking protocol.

The following communication protocol was developed to support a network of intelligent controllers. The network is implemented as a CAT-5 physical network of daisy chained RS-485 controllers. The CAT-5 cable provides a single twisted pair for RS-485 signaling and 3 twisted pair for DC power distribution.

RS-485 allows signaling over long distances (1200 meters) with up to 32 controllers on each chain. At 1200 meters, the maximum signaling speed is about 100K BPS. The DC power requirements of the daisy chained controllers limit the practical distance of the network to significantly less than 1200 meters and in the order of 100 meters. If an auxiliary power source is provided, a distance of 1200 meters should be possible.

### Protocol design requirements:

1. The protocol shall provide a message check code to allow detection of corrupt data packets.
2. The protocol shall provide message sequence numbers to allow detection of missing packets.
3. The protocol shall support a half duplex, multidrop network topology.
4. The protocol shall provide for variable length message packets.
5. The protocol shall operate at a minimum speed of 38400 BPS.
6. The protocol shall support point – point communication, with acknowledgement, and point to multipoint broadcast, without acknowledgement.
7. The protocol shall provide for continuous and periodic data packet flow so that the absence of a data packet, for a predetermined period, will be interpreted as a network failure and allow the controllers to enter a safe state.
8. The protocol shall allow the addressing of 999 physical controllers.
9. The protocol shall allow the addressing of 999 virtual controllers.
10. The protocol shall support the addressing of 9999 events (Cues).

Message Exchange. The following message exchange takes place between the system controller and the firing controllers. It should be noted than a network of half duplex controllers, sharing a common communication buss, hear messages from the master controller to the slaves as well as responses from the slaves directed to the master. Individual field units must accommodate both message flows.

Start Session:

Master Controller Message Type Direction Slave Firing Controller

Master Reset Broadcast 🡪 Resets all software and hardware to a known

Starting condition

Start Session (Unit Number) --> Firing controller

🡨 ACK

### Message Structure

All messages have one of the following message formats:

(Except for the start of message and length code, all data is 7 bit ASCII to allow the use of

Check code logic.)

#### Message Header Format

BYTE 1 X’FF’ Start of Message

BYTE 2 Message length (Binary) 1 - 255

BYTE 3 MN = Message Number Modulo 10

BYTES 4-5 Number of Work Units

BYTES 6-8 Physical Unit Address

BYTES 9-10 Command

#### Unit specific commands:

01 = Start Session

02 = Stop Session

04 = Fire Port

05 = Status (return status of e-matches, unit voltage, other device status information)

06 = Activate Trace on for Unit

07 = Save Show in EPROM

08 = Load Show from EPROM

10 = Arm Unit

11 = Disarm Unit

12 = Measure Voltage

13 = Set Default Show

14 = Save Show in EEPROM

16 = Start of Programming for Unit

17 = End of Programming for Unit

19 = Stop Unit Trace

24 = Assign Logical Address to Unit

99 = Reset Unit

#### Broadcast message (All units) commands

08 = Load Show from EEPROM

10 = Global Arm

11 = Global Disarm

20 = Pause Zone

21 = Continue Zone

33 = Set Unit Address into EEPROM

44 = Trigger Cue

95 = Poll Fast

96 = Poll

97 = Trace

98 = Current Time

99 = Reset Units

99 (Port 997) = Display Software ID and Physical Network Address on LEDs

99 (Port 090) = Send COMM Test

#### (1 – 14 work units) in the following Format

WU BYTES 1-2 Port Number

00 = Base Unit

01-nn are Port numbers

WU BYTES 3-10 Time Code in MMMMMMMM Milliseconds (Max 27 hours)

Last Byte Check Digit

### ACK Message Format

BYTE 1 X’FF’ Start of Message

BYTE 2 Message length (Binary) 1 - 255

BYTE 3 MN = Message Number Modulo 10

(Same as received message number )

BYTES 4-5 Number of WU = 01

BYTES 6-8 Host Address = "001"

BYTES 9-10 ACK Command Code = “07”

BYTES 11-29 Optional Status Information

BYTE 11|30 Message Check Code

### NAK Message Format

BYTE 1 X’FF’ Start of Message

BYTE 2 Message length (Binary) 1 - 255

BYTE 3 MN = Message Number Modulo 10

(Same as received message number )

BYTES 4-5 Number of WU = 01

BYTES 6-8 Host Address = "001"

BYTES 9-10 NAK Command Code = “08”

BYTE 11 Message Check Code

Optional Status Information

Bytes 1-3 Number of Ports on Controller (nnn)

Bytes 4-nnn Port Status 1=No eMatch conductivity, 0 = eMatch Conductivity

Byte nnn+4 Armed Status 1 = Unit Armed, 0 = Unit disarmed

Byte nnn+5 Show ID 0 = No Show Loaded, 1-2 – ID of Loaded Show.

*Bytes nnn+6 Voltage 0126 = 12.6 Volts*

*Bytes nnn+10 Phy Addr Physical Unit Address*

*Bytes nnn+13 Log Addr Logical Address*

*The Italicized values are returned in response to a Poll command*

### Specific Message Format Details

NOTE: The Start of message X”FF”, length code and ending check code are not shown. The last byte, the check code, is not shown.

#### Global Reset Message:

The purpose of the global reset message is to reset all network units to a starting condition. This sets the next send and next received message numbers to 1 and resets any active show logic. The units then await further instructions. This is a broadcast message.

C”1019999999900000000”

The breakdown of the message is:

1 = Message Number 1

01 = 1 Work Unit

999 = Unit address (All units)

99 = Reset Command

999 = Port Number (All Ports)

00000000 = 0 MS (Now)

#### Unit Start Message

The purpose of the Unit Start message is to put a unit in operational ready state.

The unit responds with an ACK message to inform the master controller that the unit is ready for further instructions. The remote’s next receive message number is incremented.

Absence of an ACK message indicates the addressed unit is not online and ready.

C”101aaa010000000000”

1 = Message Number

01 = 1 Work Unit

aaa = Physical Unit Address

01 = Start Unit Command

000 = Port Number

00000000 = Time MS (Now)

# Message Exchange Protocol

|  |  |  |  |
| --- | --- | --- | --- |
| Unit Specific Message Exchange | | | |
| Unit Reset | 🡪 | 🡨 Ack | Reset Specific Unit to start state |
| Start Session | 🡪 | 🡨 Ack | Start Specific Unit |
| Stop Session | 🡪 | 🡨 Ack | Stop Specific Unit |
| Get Status | 🡪 | 🡨 Ack + Status | Get status from Specific unit |
| Arm Unit | 🡪 | 🡨 Ack | Arm Specific Unit |
| Disarm Unit | 🡪 | 🡨 Ack | Disarm Specific Unit |
| Fire Port | 🡪 | 🡨 Ack | Fire specific Unit and Port |
| Trace On | 🡪 | 🡨 Ack | Start Trace on Specific Unit |
| Trace Off | 🡪 | 🡨 Ack | Stop Trace on Specific Unit |
| Set Default Show | 🡪 | 🡨 Ack | Sets Show to be loaded on Pwrup |
| Start Prog | 🡪 | 🡨 Ack | Load Program for show N |
| Stop Prog | 🡪 | 🡨 Ack | End Prog for show. |
| Save Show | 🡪 | 🡨 Ack | Save show in EEPROM slot 1-3 |
| Load Show | 🡪 | 🡨 Ack | Load Show from EEPROM slot 1-3 |
| Broadcast to All Units | | | |
| Master Reset | 🡪 |  | Reset All Units |
| Time (Sent every n sec after units are armed) | 🡪 |  | Sync All Clocks  (Also acts as keep alive for armed units) If not heard in 15 sec, disarm unit. |
| Load Show (1-3) | 🡪 |  | Loads show N from EEPROM |
| Arm all units | 🡪 |  | All Units Arm |
| Disarm All Units | 🡪 |  | All Units Disarmed |
| Fire CUE N | 🡪 |  | Starts CUE N |
| Set Address | 🡪 |  | Sets Unit Address into controller  (Must be sent twice in succession)  (Only desired unit to be programmed must be online) |
| Poll | 🡪 | Delay 🡨 Ack + Status | Polls Online Units |

Typical Session of starting three Units, arming them and firing specific ports (Manual Fire), then resetting them and entering Start State.

Master Reset 🡪 (All Units enter Start State)

Start Unit 10 🡪

🡨 ACK (Unit 10 activated)

Start Unit 11 🡪

🡨 ACK (Unit 11 activated)

Start Unit 12 🡪

🡨 ACK (Unit 12 activated)

Arm Unit 10 🡪

🡨 ACK (Unit 10 Armed)

Arm Unit 11 🡪

🡨 ACK (Unit 11 Armed)

Arm Unit 12 🡪

🡨 ACK (Unit 12 Armed)

Time 🡪 (Broadcast every 5 seconds to keep armed units alive)

Time 🡪

Time 🡪

Fire Unit 10, Port 1 🡪

🡨 ACK (Unit 10, Port 1 Fired)

Fire Unit 12, Port 5 🡪

🡨 Ack (Unit 12, Port 5 Fired)

Time 🡪

Time 🡪

Master Reset 🡪 (All Units disarm and return to Start State)

## Auto Recovery

The field modules incorporate an Auto-Recovery feature that functions to allow a rapid module restart in the event of an intermittent power failure or Reset operation. In normal operation, it may be possible for a cable to work loose or be affected by the shock of a neighboring mortar. In the event of an intermittent circuit, a Power-On Reset is executed and the field units will restart and re-establish a session but they will not automatically re-arm. Delaying an automatic re-arm is a safety measure which requires the show operator to explicitly issue Arm commands.

To determine if the required field modules are armed, a unit specific “Status request” message or “Global Poll” command is issued. The field modules will respond with their status, including the “Armed” status. If any field modules respond “Not Armed” and they should be armed. The operator needs to re-issue an Arm command. This can either be a unit specific “Arm” command or a “Global Arm” command.

For this function to work during a show, the show needs to be loaded into the field module and the loaded show needs to be stored in EEPROM and set as a DEFAULT show. When this is done, the required show is automatically re-loaded when a “Power On Reset” operation is executed. The field module then needs to be re-armed and the show can continue without disruption.

Typical Protocol for an automatic re-start during a show:

Master Reset 🡪 (All Units enter Start State)

Start Unit 3 🡪

🡨 ACK

Prog Unit 3 🡪

🡨 ACK

Programming Data 🡪

🡨 ACK

Prog Unit 3 🡪

🡨 ACK

Prog Data for Unit 3 🡪

🡨 ACK

End Prog Unit 3 🡪

🡨 ACK

Start Unit 3 🡪

🡨 ACK

Get Unit 3 Status 🡪

🡨 ACK + Status

Stor in EEPROM 🡪

🡨 ACK

Set Default Prog 🡪

🡨 ACK

Arm Unit 3 🡪

🡨

/////////////// Power on Reset /////////////////

Unit 3 restarts, reloads default show from EEPROM

Poll 🡪 (All Units Polled)

🡨 Unit 3 response (Not Armed, Show loaded))

Operator issues Global Arm

Global Arm 🡪 (All Units re-armed)

Poll 🡪 (All Units Polled)

🡨 Init 3 response (Armed, Show Loaded)

Time 🡪

Time 🡪

Fire Cue n 🡪

Master Reset 🡪 (All units reset, disarm and end sessions)

## Poll Fast

A Fast Poll is designed to return all pertinent Field Module information except the port status.

The Fast Poll is used during network setup, to determine which units are active and during show execution, to determine which units may have been reset and are un-armed.

The Fast Poll contains network topology information is place of the usual WU information.

The Network Topology information is a string containing a 3 byte numeric field for each bank of 100 field units.

Bytes 1-3 = Number of units in Bank 0, Physical addresses 3-99

Bytes 4-6 = Number of units in Bank 1, Physical Addresses 100-199

Bytes 7-9 = Number of units in Bank 2, Physical Addresses 200-299

.

.

.

Bytes 25-27 = Number of units in Bank 9, Physical Addresses 900-998

The Field modules, upon receiving a Fast Poll message, compute the amount of delay necessary before responding. They use 10 Milliseconds per unit and calculate all units with addresses preceding their own. This allows an orderly set of replies.

Since no port status information is returned, each Field Module requires only about 5.7 Milliseconds for its reply. 10 Milliseconds is allocated for each unit to allow a small space between response messages.

Because the Field Modules do not wait for units that are not on the network, the Poll operation is completed in the shortest possible time.

Each response is composed of 25 characters. This requires 5.7 Milliseconds per active field module.

A network, consisting of 50 field modules, can thus be Fast Polled in ½ second. The returned responses contain the number of ports in the module, the physical unit address, the logical unit address, the armed status, the loaded show status and the measured voltage.

The number of ports on the Field Module is returned and is used by the PC to Broadcast to the network in 1 or a series of broadcast transmissions. The information in these transmissions consists of 1 or more information pairs that contain the module address and number of ports. Information of a maximum of 24 modules is contained in each broadcast. The information is in the format AAADDDDD where AAA is the physical address and DDDDD is the module reply delay in MS. If the network contains more than 24 modules, multiple broadcast messages are used.

This information is used by the field modules when responding to Slow Poll operations where the port status information is included in the poll response. The field modules use the broadcast delay before responding.

The delay is computes as 7 MS per module plus .26MS per port. A module with 16 ports is allocated 12 MS, a module with 144 ports is allocated 45MS and a module with 430 ports is allocated 119 MS. This minimizes the Slow Poll response time

As an example of the time required to poll 50 modules (25 16 port modules and 25 144 port modules), is calculated as :

Fast Poll = 50 \* .01 sec = .5 Sec

Slow Poll = 25 \* 12MS = .3 Sec + 25 \* 45MS = 1.1 sec (Total = 1.4 sec)

The total time to poll the above network is approx 2 sec.