CEGELEC

INDUSTRIAL CONTROLS

Contents

GEM80 Serial Links

This document provides comprehensive technical information about standard GEM80 20mA current loop serial links. It contains all the guidance which a user may need to construct and operate serial links between GEM80 controllers.

A definition of ESP protocol and standard GEM80 messages is included, to enable users to program computers to communicate with GEM80 systems.

1. INTRODUCTION

1.1 Types of port

A typical GEM80 controller includes one or more built-in serial ports from which the user can construct serial links. The ports may be of three types:-

(a) Control port
(b) Tributary port
(c) Printer port

Control and tributary ports are used for serial links between different GEM80 systems, using the standard GEM80 Extended Simple Protocol (ESP). ESP links have high integrity because of the built in automatic checking, including a 16 bit cyclic redundancy check in every message. A printer port provides a simple serial interface for ASCII characters to proprietary devices such as printers, VDUs and keyboards.

Early GEM80 controllers had ports of a predetermined type which could not be altered. Controllers released since Spring 1981 have user configurable ports which can be changed from one type to another by alteration of configuration data set up by the user.

For details of the ports in any particular GEM80 controller, refer to the appropriate Product Data Sheet.

USER INFORMATION

1.2 Point-to-point and multidrop

A GEM80 serial link comprises one control port communicating with one or more tributary ports. If there is only one tributary, the link is called a point-to-point link (Fig.1). If there are several tributaries, it is called a multidrop link (Fig.2).

Fig.1 Point-to-point link

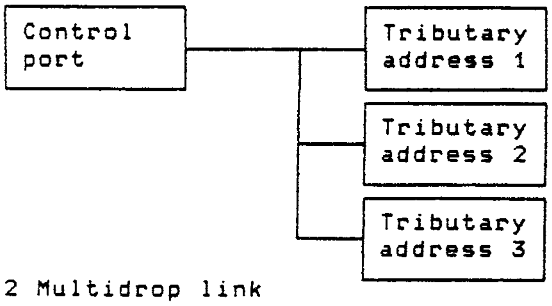


Fig.2 Multidrop link

The control port is responsible for all the activity on the link; a tributary port responds only when a message is addressed to it, inviting it to reply. The control port on a multidrop link communicates with each tributary, on a cyclic basis. Communication directly between tributaries is not possible, though data can of course be passed via the control port.

The number of tributaries which can be connected in a multidrop link depends on the firmware capability built into the controller containing the control port. Examples:-

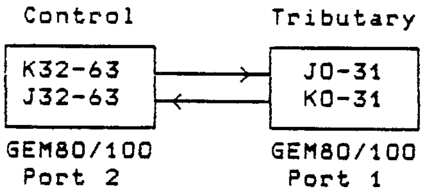
Control port	No. of tributaries
GEM80/250	8
GEM80/235	7
GEM80/130(12K)	4
GEM80/100	1

1.3 Data table exchange

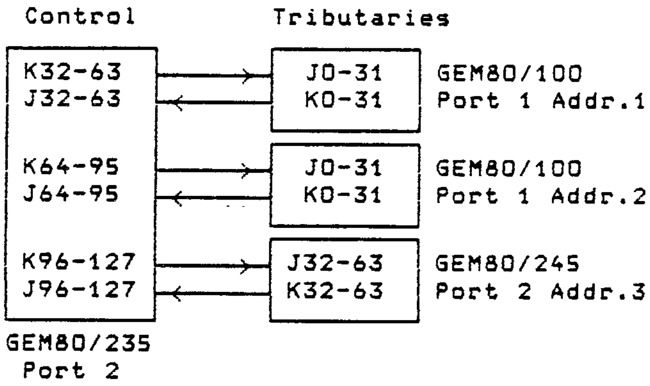
The simplest and most common type of serial link is between controllers each with their own user program and their own data tables. Serial links between GEM80 controllers work by exchanging data between areas of data tables reserved for each port.

The ports built into the processor module of a standard GEM80 controller use J and K tables for serial input and output respectively. Data placed in K table locations by the user program at one end of the link appear automatically in J table locations at the other end of the link, after a time delay due to the link activity.

A block of table locations is reserved for each port, and for each possible route from a multidrop control port. (Note - MINIGEM re-uses same block for all routes).



(a) Point-to-point link



(b) Multidrop link

Fig.3 Typical table usage

Notice that the location numbers depend on which port in a controller is used, and there is typically an offset of a multiple of 32 between corresponding location numbers at opposite ends of the link. Configuration data at each end of the link determines the quantity of locations actually exchanged, which is always a contiguous group at the bottom end of the reserved block.

1.4 Tributary address

Any tributary port is equally suitable for use on a point-to-point or multidrop serial link. Communication can be established only when the user selects a tributary address to suit the control port of the link.

This is usually achieved by the user entering configuration data in the controller's preset data table.

The simplest type of control port is restricted to point-to-point working only, and uses tributary address zero. Multidrop control ports use a contiguous block of tributary addresses, starting from 1 in the GEM80/100, 130, and 235 series of controllers, and starting from 0 in the GEM80/250 series.

GEM80 Serial Links

T418 Issue 3 03/85

Please incorporate the following amendments:-

Page 6, Fig.7, Pin 13

Delete COMSCN
Insert SCREEN

Page 13, Item (b)

Opposite 2,400 and under column 7

Delete 1.9
Insert 1.0

Please retain this Errata Sheet with the document for reference.

A multidrop control port can be used on a point-to-point serial link, in which case the user can choose any one of the available addresses, typically the lowest.

2. TIMING OF ACTIVITY

2.1 Initiation of transmission

Early GEM80 controllers have no facility for the user program to influence the time at which a message transmission is initiated, and their serial ports are said to be "free running".

Recent GEM80 controllers (e.g. the 250 series) include the option of a "free running" mode identical to that in early controllers, and an alternative "user control" mode. The latter enables the user program to control by means of a flag the instant at which data is taken from the K table and transmission commenced.

A "free running" control port will start transmitting its first message immediately after power up, and subsequent messages will be sent either when a reply has been received, or a timeout period has elapsed. If the "user control" mode is selected, then the snapshot copy of the K table will not be taken until the appropriate flag has been set by the user program.

A "free running" tributary port will reply immediately that the data of a received message has been copied into the J table, and the K table data as sent will take no account of the J table data just received. If the "user control" mode is selected, then the snapshot copy of the K table data will not be taken until the appropriate flag has been set by the user program.

2.2 Interlock with program scan

Although serial link activity is distributed through a controller's operating cycle, the transfer of data to and from data tables is allowed only between program scans.

If a valid message is received in mid-scan, then there is a delay until the end of the program scan, when a "snapshot" copy is made of received data to the J table. If the port is "free running", then a "snapshot" copy of the K table is made at the same instant, and the reply commences. If the "user control" mode is selected, then the "snapshot" copy of the K table is not taken until the end of the program scan in which the appropriate flag is set.

The interlocking means that serial I/O data cannot change during a program scan.

A multidrop control port communicates with only one tributary at a time. Unless the gap between program scans is long enough for a complete link exchange, then the "snapshot" of new J/K table data between scans will apply to only one route.

If a controller has a short program execution time and is set to run with a long program repetition interval, then it is possible for several link exchanges to occur between scans. At the other extreme it is possible for the program to be scanned several times during a single link exchange.

2.3 Interval between exchanges

There will be some variation in the interval between data exchanges over a serial link, because of the independent timing of the operating cycles at each end of the link.

If the link is "free running", then the longest interval will occur when the end of each message is just after the start of a program scan, and the overall time will be the sum of the two program execution times plus the signalling time on the link.

The shortest interval will be when the end of each message comes between program scans, and the overall time will be just the signalling time.

If the "user control" mode is selected at a control port, then the timing of messages at the control port is determined by the setting of the control flag by the user program, and the user could if desired choose very long intervals between messages.

If the "user control" mode is selected at a tributary port, then the user should avoid delaying the reply too long, because the control port will eventually time out, and abort that exchange. Typically, there will be ample time to allow one scan of the user program between receiving a message and initiating the reply.

2.4 Signalling time

Serial link signalling time is inversely proportional to the signalling rate in bits per second. The user will normally choose the fastest possible signalling rate, within the limitations of link length and quantity of tributaries on the link. The signalling time may be minimised by choosing to exchange a small quantity of J/K table locations.

An approximate value of signalling time (total for one message in each direction neglecting any delay between messages) at 9600 bit/s is 12.5ms plus 2.5ms per table location exchanged. The value is approximate because the data is transmitted in binary form, and "byte stuffing" is required for 6 out of the 256 possible combinations for a byte. For characters with a hex. value @2,@3, @4,@5,@10,or @17 an extra byte is needed to indicate that the following character is not a control character.

Because of byte stuffing the time per table location at 9600 bit/s can vary between 2.1 and 4.2ms depending on the data pattern.

3. CABLE ARRANGEMENT

3.1 20mA current loop

Standard GEM80 serial ports are designed for 20mA current loop working. Each loop has a 20mA current source derived from the internal 15V power supply of the GEM80 controller, an optically isolated switch for controlling the current, and an optically isolated current sensing load.

The optical isolation eliminates problems due to earth loops and differences in earth potential, and allows relatively long links to be constructed at low cost without the need for modems. It also allows series connection of several switches and/or loads, subject only to the limitation of the total voltage available to drive the current around the loop.

3.2 Fibre-optic cable

The 8927 Fibre-Optic Transceiver provides an interface between the 20mA current loop operation of the ports of a GEM80 controller, and a fibre-optic cable.

The optical communication option offers the ultimate in safety, noise immunity and isolation.

Unlike electrical transmitters and receivers, it is not possible to arrange fibre-optic transceivers in series in a multidrop cable. Optical serial links have therefore to be cabled on a point-to-point basis, and multidrop working is achieved by having several transceivers at a multidrop control port each cabled point-to-point to one tributary port.

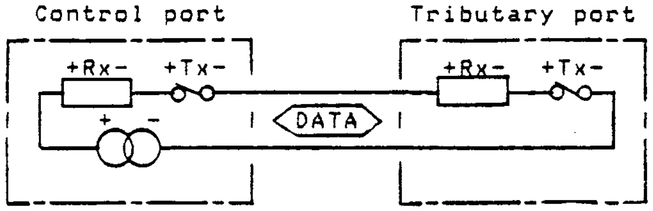
3.3 Single and twin pair cables

Communication on GEM80 serial links is half duplex. This means that at any instant in time information can be flowing in only one direction, and a single pair of wires is sufficient to convey information in both directions.

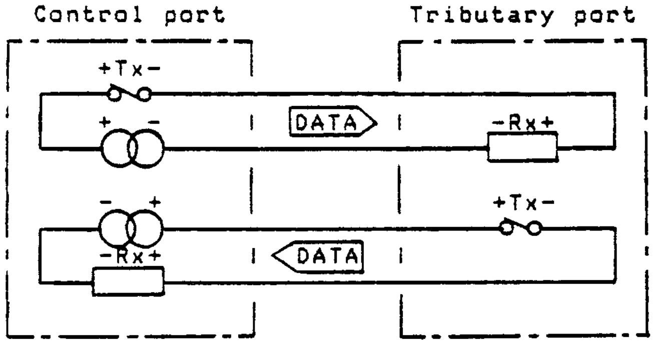
The user can choose to run his cabling for a serial link either as a single pair of wires or as a twin pair. The use of a single pair is economically advantageous for any link exceeding approximately a hundred meters in length, because of the substantial saving in cable cost. A twin pair cable may however be needed if signalling time is critical or a very long link is required, because the extra volt drop across the additional devices in series effectively reduces the voltage available for driving the current around the loop.

There is a minor software restriction which arises if a single pair cable is used for a multidrop link. Each tributary must be configured to transmit at least one word of data along the link, otherwise the "acknowledge" reply will cause the failure of the first message to the next tributary on the link. The automatic retry will allow recovery from the failure, but the situation should be avoided because of the time delays involved.

Figs 4 and 5 illustrate the circuits for typical serial links. There is no particular significance in the order in which the switches and loads are connected, but the polarity markings are important and must be observed.

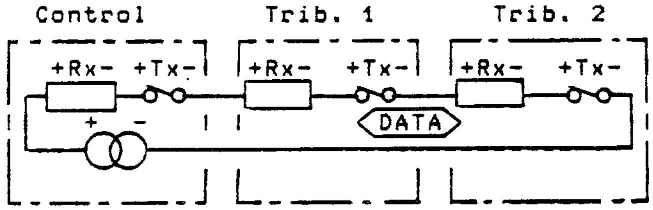


(a) Single pair cable

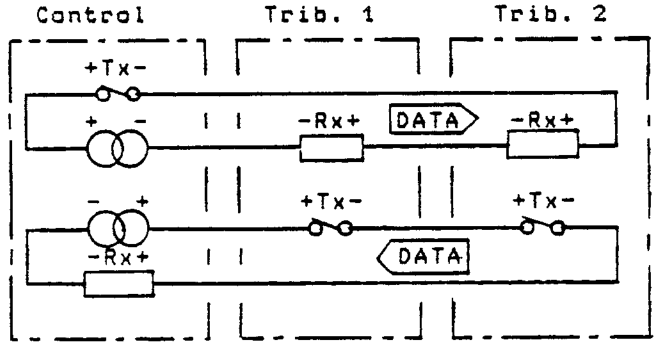


(b) Twin pair cable

Fig.4 Circuits for point-to-point link



(a) Single pair cable



(b) Twin pair cable

Fig.5 Circuits for multidrop link

3.4 Choice of termination panels

A typical GEM80 controller has a number of independent serial ports, brought out via ribbon cable connectors. If the user wishes to construct serial links, he should order serial link termination panels or units for each port in the link, according to the type of controller.

Controller type	Termination unit 1 pair	Termination unit 2 pair
100/130/225/235/245	8925	8038
8845/8847/8860/8861	8925	8038
250	8924	8924
MINIGEM	8655	8655

A typical serial link may have a mix of different equipment at the various ports in the serial link.

Earlier controllers require different termination units for single or twin pair cabling. Later types are suitable for either.

The 8038 panel is for two ports, the others are for one port only.

MINIGEM does not require a separate termination panel, because the plant cables are terminated directly on the serial I/O minimodule.

The termination units are fitted with continuity devices which allow a multidrop serial link to continue operating even if one (or more) of the tributaries is powered off, or is being repaired by replacement of the processor module. The continuity devices provide a path for the 20mA signalling current.

For optical serial links, a transceiver type 8927 is required for each tributary and for each route from a control port. Controllers type 100/130/235 etc can have the 8927 connected to the ribbon cable from the controller in place of the 8038 or 8925 termination unit. The 250 series and MINIGEM can use a fibre-optic transceiver, but it has to be connected externally after the 20mA interface.

3.5 Termination unit type 8925

This unit is used to construct single pair serial links from GEM80 equipment of the following types:-
Controllers :100/130/225/235/245
Fast I/O :8845/8847/8860/8861

The serial link ribbon cable from the host controller is plugged into one or other of the two connectors on the termination unit, depending on which of the two ports of the GEM80 controller is to be connected to the serial link.

Typically the ribbon cable may be looped to continue to another termination unit for the second port of the controller.

A single 20mA current source is brought out to the terminals of the 8925 unit. At a control port, the current source is normally used to supply the signalling current. At a tributary port, the current source may be linked to the the coil of a bypass relay, and the pair of "bypass" terminals linked to each other to provide continuity of the 20mA loop. The relay contact provides continuity when the controller is powered off, and when the processor module is absent.

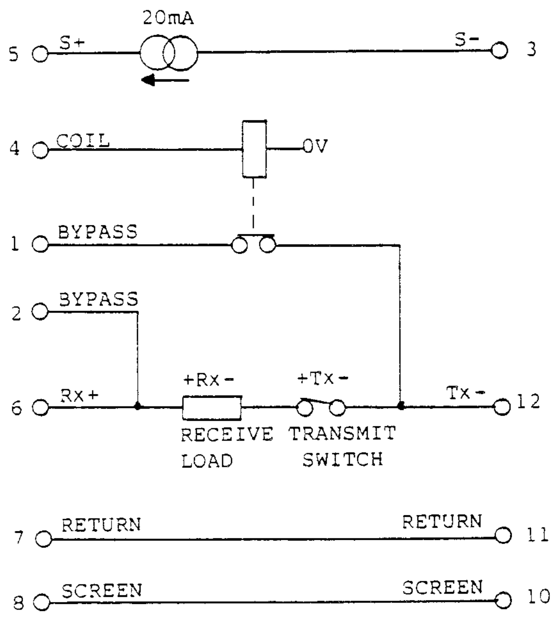


Fig.6 Details of unit type 8925

3.6 Termination panel type 8038

This unit is normally supplied as part of a kit type 8871-4002. It is used to construct twin pair serial links from GEM80 equipment of following types:-
Controllers :100/130/225/235/245
Fast I/O :8845/8847/8860/8861

Zener diodes are provided on the termination panel in parallel with each receive load, to provide circuit continuity when the processor module is absent. The receive load on the processor module conducts and provides circuit continuity when the processor is powered off.

Plug-in relays are available to provide continuity at each transmit switch when the processor is powered off, or the processor module is absent. RL1 and RL2 are plug-in relays, fitted according to the re-order number of the panel. The relay should be fitted when it is required to provide continuity at a tributary port. It should not otherwise be fitted, because the coil loads one of the current sources.

Panel type	Fitted	Panel type	Fitted
8038 4002	RL1	8038 4007	RL1,RL2
8038 4003	-	8038 4008	RL2

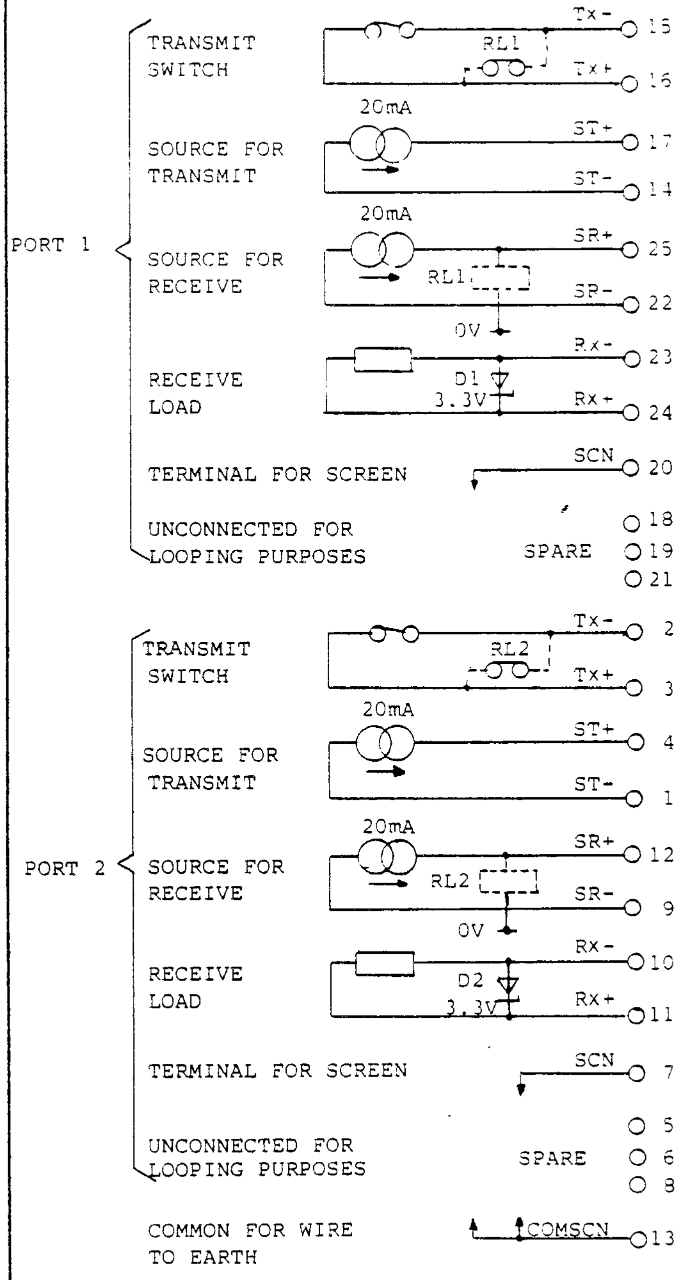


Fig.7 Details of panel type 8038

3.7 Termination unit type 8924

This unit is used to construct single and twin pair 20mA serial links from GEM80 250 series controllers.

The serial link ribbon cable from a 250 series I/O processor carries a pair of serial ports. Typically, the ribbon cable is looped to continue to a second termination unit for the other port. Selection of the 2nd port is made by an external link made by the user.

When a controller is fitted with two I/O processors, then the master I/O processor provides ports 1 and 2, and the slave I/O processor provides ports 3 and 4.

The receive load within the termination unit will conduct and provide circuit continuity if the controller is powered off, or the processor is absent. A reed relay within the termination unit provides circuit continuity via the transmit switch if the controller is powered off, or the processor is absent.

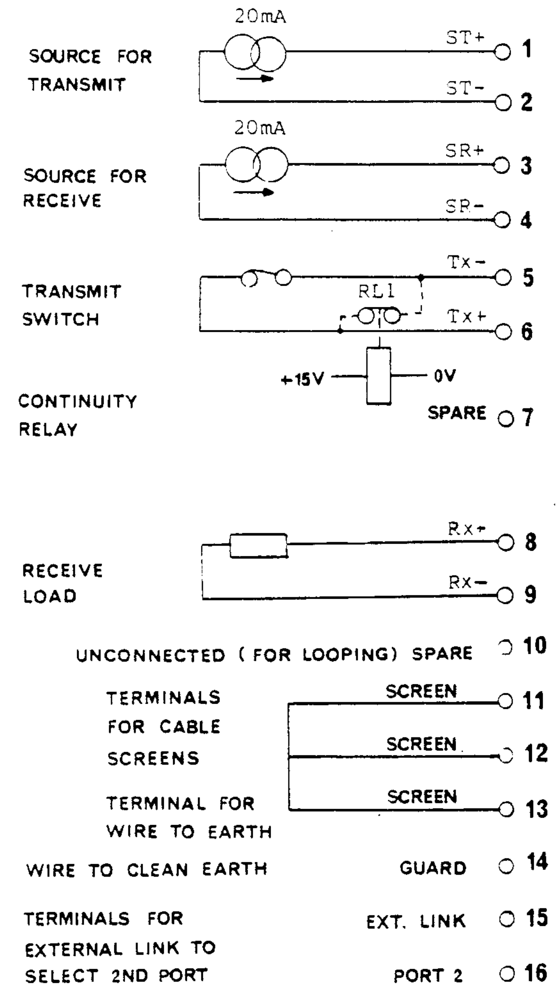


Fig.8 Details of unit type 8924

3.8 Serial I/O minimodule type 8655

This minimodule is used to construct single or twin pair 20mA serial links from MINIGEM controllers.

The minimodule fits into the MINIGEM controller, and provides a set of terminals for the termination of the plant cables. A separate termination panel is not needed.

The minimodule generates an isolated 15V power supply, which is used for the pair of 20mA current sources provided. The negative returns of the current sources are internally connected to the 0V of the isolated power supply. It is not necessary to connect this point to earth, but it can be if desired.

The minimodule contains a FET transistor in parallel with the transmit switch, which provides continuity of the 20mA loop when the MINIGEM is powered off. The receive load conducts and maintains circuit continuity when the MINIGEM is powered off.

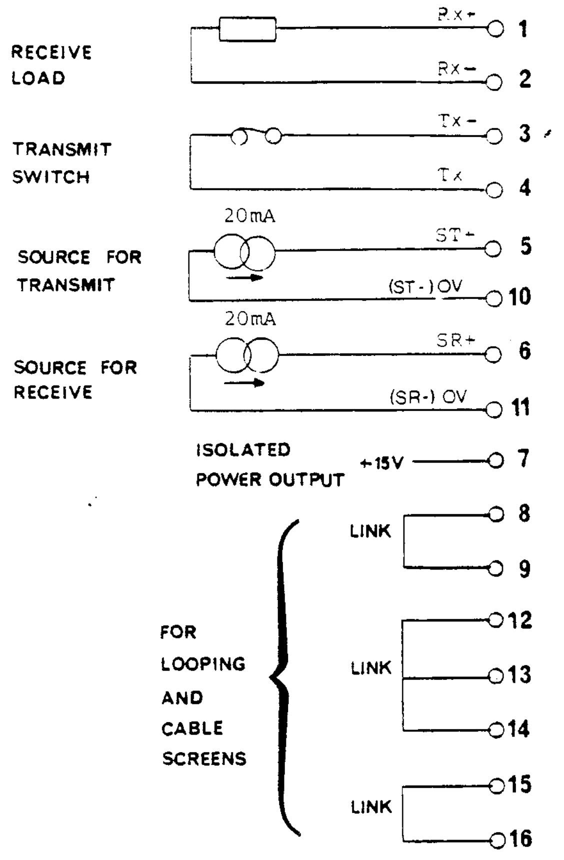


Fig.9 Details of minimodule type 8655

Unlike GEM80 controllers with plug-in processor modules, it is not possible to unplug the processor part of a MINIGEM controller for repairs. Instead it is necessary to replace the entire unit, including the serial I/O minimodule. If the user wishes to maintain the continuity of the 20mA loop whilst substituting a spare MINIGEM, then it is recommended that an external plug and socket should be fitted to allow the serial link wiring to be disconnected from the MINIGEM, and a suitable shorting plug inserted to maintain the continuity of the serial link whilst the MINIGEM is disconnected.

3.9 Terminal numbering

The equivalent terminals for the two ports on an 8038 termination panel have identical code markings. Each terminal is therefore additionally labelled with a unique terminal number, which is intended to be used for unambiguous terminal designation on cable schedules.

The terminals on the 8924, 8925 and 8655 units are similarly numbered for use on cable schedules.

Since a GEM80 controller can have more than one serial link termination panel or unit, it is recommended that each panel/unit should be identified by the position to which the ribbon cable runs (e.g. R0/10 for rack ref. R0, slot position 10), and the port number. This code should then be used as a prefix for the terminal numbers, making them unique for the system. Thus a typical 8038 terminal reference would be R0/10/Port1/24 for port 1 Rx+ (equivalent for 8925 would be R0/10/Port1/6). Similarly for MINIGEM, it is recommended that the table locations associated with the minimodule position should be used as the terminal number prefix, giving a typical reference JK100/6 for Rx+ on minimodule in physical position 1.

3.10 Port providing current source

It is conventional for the current sources of a link to be provided by the control port of the link. For a multidrop link this offers the ability to continue operating the link with any one of the tributaries switched off, albeit with a slower response due to failed attempts at communication with the tributary which is switched off. For a point-to-point link, or a system which cannot in any case tolerate one of the tributaries being switched off, it is equally suitable for a tributary port to provide the current sources. This may be advantageous if the tributary has a higher driving voltage available for the loop, or may be essential when communicating with proprietary equipment with crude or non-existent current sources.

3.11 Cable routing

The electrical circuit of a multidrop serial link requires the wires to visit each tributary in turn. The order of the tributaries is immaterial, and the cable routing can be arranged to suit the plant layout. For example, any of the ports could be used as a "star" point, or they could be in a linear chain.

In all cases it is important for the "go" and "return" wires to be run together to minimise noise pick-up, and twisted pair cables plus screening are advisable for the same reason. Spare terminals are provided on the termination panels and units to allow looping at intermediate points in the link.

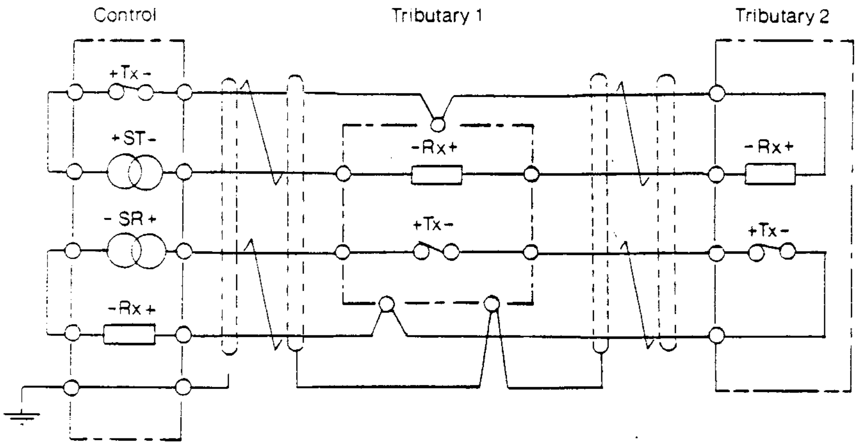
3.12 Typical circuits

Fig.10 to 13 show typical circuits for serial links using the various types of termination units. In each case a multidrop serial link is used as the example, so that connections are illustrated for a control port, an intermediate tributary port, and the tributary at the end of the serial link.

The circuits for a point-to-point link, or a more extensive multidrop serial link, may be derived by simplifying or extending these examples. Similarly, a serial link using a mix of types of termination units may be derived by combining parts of the circuits from each of the examples.

Each pair of the twin pair cable can be a separate screened cable if multi-pair screened cable is not available.

In all cases cable screens should be earthed at one end only, normally at the port providing the current sources. Notice that a few short wire links are necessary in addition to the twisted pair cables between stations. Notice also the use of spare unconnected terminals for looping of signal and screen conductors.



Two sets of terminal numbers are shown. Those in brackets apply to port 2.

Fig.10 Typical twin pair wiring using 8038 panels

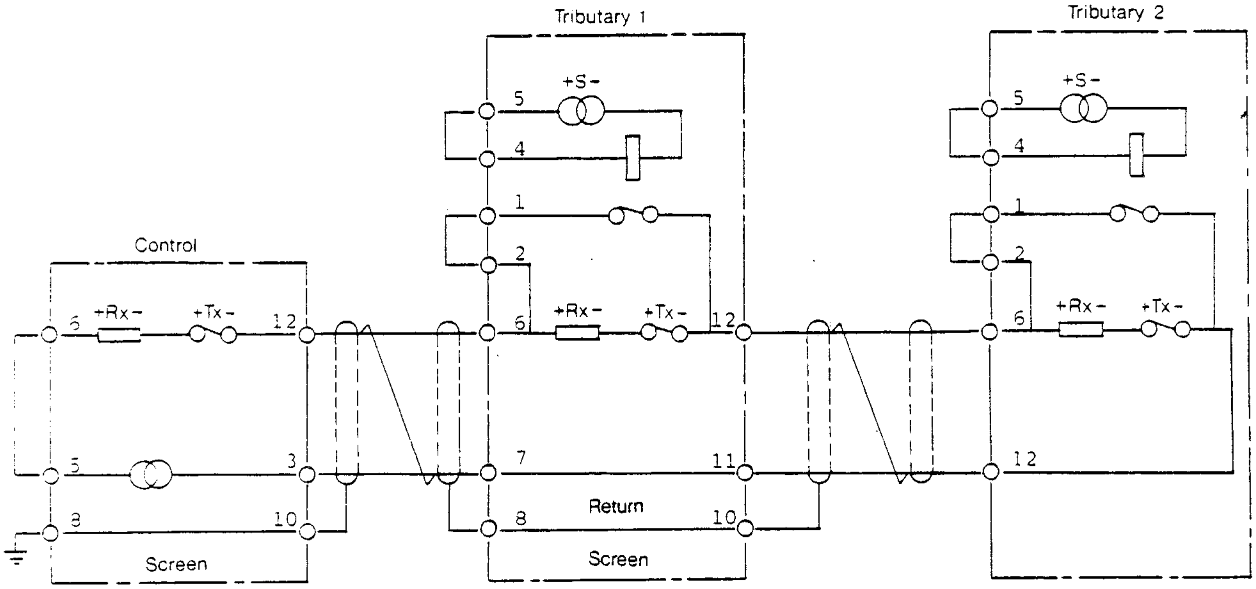


Fig.11 Typical single pair wiring using 8925 units

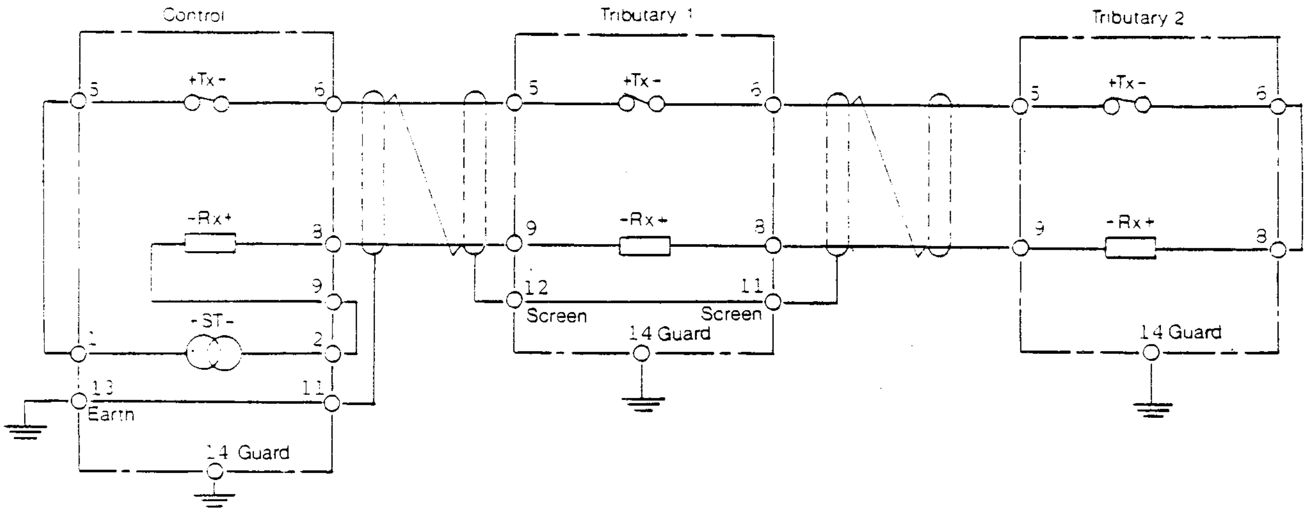


Fig.12a Typical single pair wiring using 8924 units

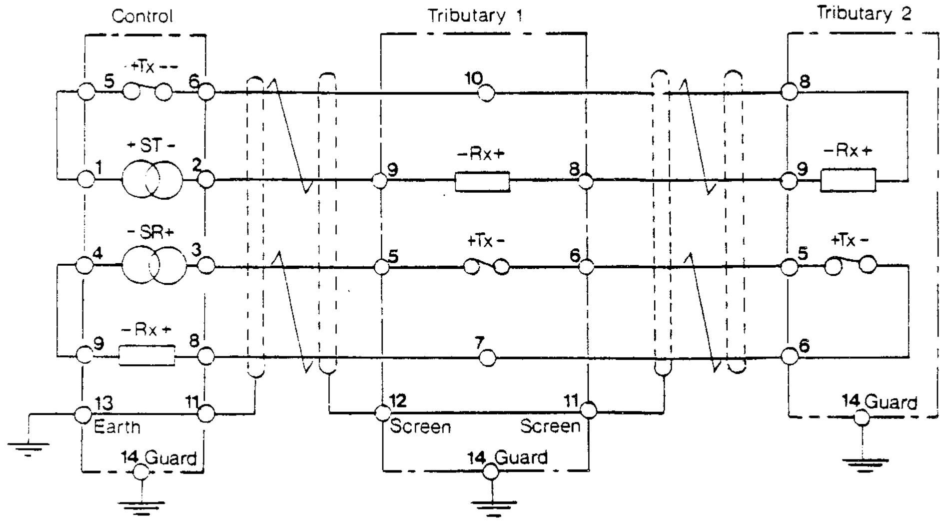


Fig.12b Typical twin pair wiring using 8924 units

NOTES:-

Guard terminals optionally connected to clean earth
for optimum noise immunity.

Additional wire link is required between terminals
15 and 16 when port 2 (or port 4) of controller is used.

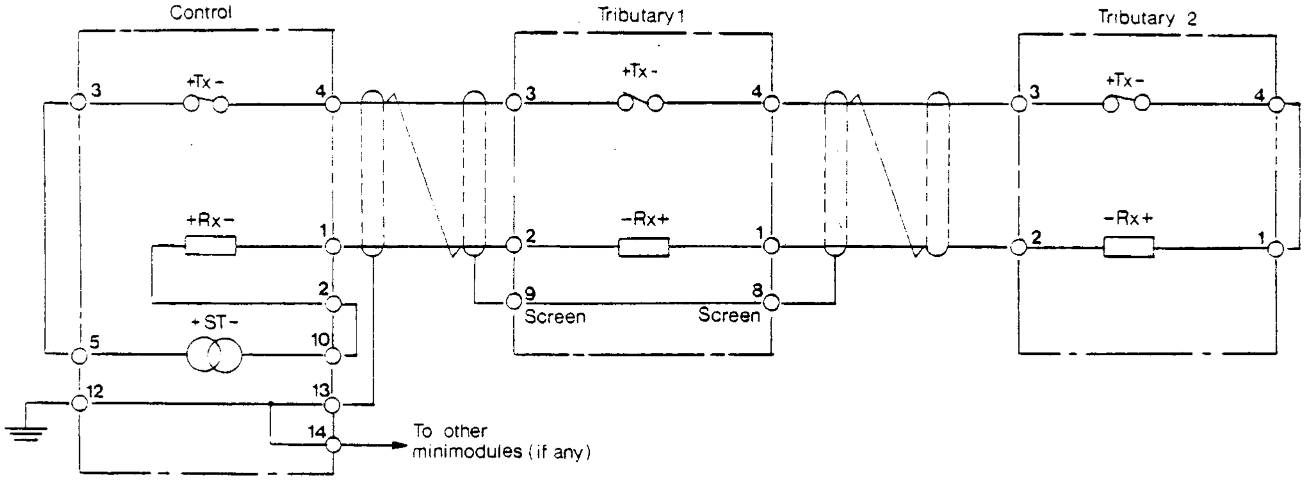


Fig. 13a Typical single pair wiring using 8655 minimodules

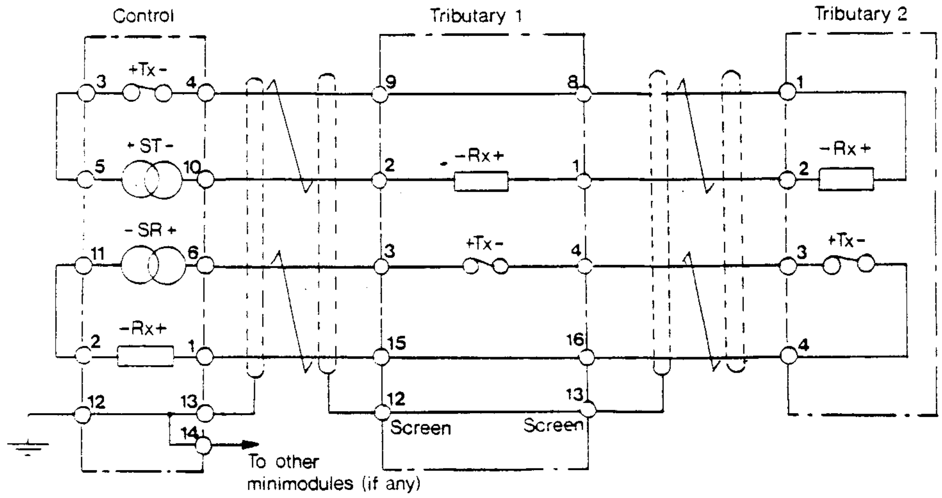


Fig.13b Typical twin pair wiring using 8655 minimodules

4. SPEED/DISTANCE LIMITATION

4.1 Limiting factors

The maximum length of optical serial links is determined by the attenuation of the transmitted light, and is not affected by signalling speed.

For 20mA current loop links, signalling speed is limited partly by the response time variation of the transmit switches and receive loads, but mostly by the time taken to charge and discharge the mutual capacitance between the cores of the cable, and between the cores and the screen.

There is an overall length limitation due to the volt drop in the cable, which is independent of signalling rate. Any link may be extended beyond the limits due to 20mA working, by introducing proprietary modems. Modems allow very long links, limited by propogation delays, which may give timeout problems if they exceed 100ms.

The maximum link length depends on:-
(a) Driving voltage provided by current sources (15V or 30V in standard GEM80 equipment, depending on whether -15V power rail available. 15V applies to MINIGEM and GEM80/100 series, 30V to GEM80/200 and 250 series.)
(b) Choice of single/twin pair cable.
(c) Signalling rate.
(d) Cable capacitance and resistance.
(e) Quantity of tributaries in link.
(f) Presence anywhere in serial link of a termination unit type 8925.
(g) Presence at 20mA current source of clamping circuit, preventing cable charging through large voltage swing.
(h) Volt drop of transmit switches and receive loads. Standard GEM80 circuits have a typical 1.0V volt drop for Tx, and 1.1V to 1.5V volt drop range for Rx. The quoted figures will be applicable to non-GEM80 equipment with equivalent volt drop characteristics.

4.2 Limits for typical cable

The figures which follow apply to standard GEM80 serial ports connected via a cable with core resistance 40 ohm/km, and capacitance of 180nF/km measured from one core to the other cores plus screen all connected in parallel. These figures are representative of a screened twisted pair cable with 0.5sq mm cores (e.g. 16/0.2 mm).

The supply voltage depends on the type of controller providing the current sources (normally the control port). If it is a requirement to operate the link with one or more tributaries unplugged, then the length limit may be affected, and may be calculated using the formulae given in section 4.3.

The feature of "current source clamping" is being introduced as an option which can be provided by wiring an add-on external circuit to the current source. In due course it is expected that certain types of termination panels may be made available with built-in clamping circuits.

(a) Single pair, 15V supply,
no 8925 units anywhere in link,
current sources not clamped.

RATE BIT/S	LENGTH(km) FOR GIVEN NO OF TRIBS 1	2	3	4	5	6	7	8
9600	.24	.31	.45	0	0	0	0	0
4800	.82	1.1	1.4	0	0	0	0	0
2400	2.4	3.0	1.4	0	0	0	0	0
1200	4.5	3.0	1.4	0	0	0	0	0
600	4.5	3.0	1.4	0	0	0	0	0
300	4.5	3.0	1.4	0	0	0	0	0
110	4.5	3.0	1.4	0	0	0	0	0

(b) Single pair, 30V supply,
no 8925 units anywhere in link,
current sources not clamped.

RATE BIT/S	LENGTH(km) FOR GIVEN NO OF TRIBS 1	2	3	4	5	6	7	8
9600	.1	.11	.12	.13	.15	.17	.21	.25
4800	.31	.34	.38	.43	.49	.58	.70	.86
2400	.76	.84	.94	1.0	1.2	1.5	1.9	1.1
1200	1.7	1.9	2.2	2.5	3.1	4.2	2.7	1.1
600	4.0	4.6	5.7	7.4	5.8	4.2	2.7	1.1
300	12	10	8.9	7.4	5.8	4.2	2.7	1.1
110	12	10	8.9	7.4	5.8	4.2	2.7	1.1

(c) Single pair, 15V supply,
8925 unit(s) used in link,
current sources not clamped.

RATE BIT/S	LENGTH(km) FOR GIVEN NO OF TRIBS 1	2	3	4	5	6	7	8
9600	*6m	*8m	.01	0	0	0	0	0
4800	.56	.74	1.1	0	0	0	0	0
2400	2.0	3.0	1.4	0	0	0	0	0
1200	4.6	3.0	1.4	0	0	0	0	0
600	4.6	3.0	1.4	0	0	0	0	0
300	4.6	3.0	1.4	0	0	0	0	0
110	4.6	3.0	1.4	0	0	0	0	0

* Figures marked * are metres NOT km.

(d) Single pair, 30V supply.
8925 unit(s) used in link,
current sources not clamped.

RATE BIT/S	LENGTH(km) FOR GIVEN NO OF TRIBS 1	2	3	4	5	6	7	8
9600	*2m	*2m	*3m	*3m	*4m	*4m	*5m	*6m
4800	.22	.24	.26	.30	.34	.39	.48	.60
2400	.66	.73	.81	.92	1.1	1.3	1.6	1.1
1200	1.6	1.8	2.0	2.3	2.8	3.8	2.7	1.1
600	3.8	4.4	5.4	7.4	5.8	4.2	2.7	1.1
300	12	10	8.9	7.4	5.8	4.2	2.7	1.1
110	12	10	8.9	7.4	5.8	4.2	2.7	1.1

* Figures marked * are metres, NOT km.

(e) Twin pairs, 15V supply,
current sources not clamped.

RATE BIT/S	LENGTH(km) FOR GIVEN NO OF TRIBS 1	2	3	4	5	6	7	8
9600	.20	.21	.24	.27	.30	.35	.42	0
4800	.66	.73	.81	.93	1.1	1.3	.50	0
2400	1.7	2.0	2.4	3.1	2.4	1.4	.50	0
1200	6.1	5.2	4.2	3.3	2.4	1.4	.50	0
600	6.1	5.2	4.2	3.3	2.4	1.4	.50	0
300	6.1	5.2	4.2	3.3	2.4	1.4	.50	0
110	6.1	5.2	4.2	3.3	2.4	1.4	.50	0

(f) Twin pairs, 30V supply, current source not clamped

Rate bit/s	Length(km) for given number of tributaries 1	2	3	4	5	6	7	8
9600	.10	.10	.11	.11	.12	.12	.13	.14
4800	.32	.34	.35	.37	.39	.41	.44	.47
2400	.78	.82	.87	.91	.97	1.0	1.1	1.2
1200	1.8	1.9	2.0	2.1	2.2	2.4	2.6	2.9
600	4.2	4.5	4.9	5.4	6.3	7.0	6.1	5.1
300	12	11	9.9	8.9	8.0	7.0	6.1	5.1
110	12	11	9.9	8.9	8.0	7.0	6.1	5.1

(g) Twin pair, 15V supply,
current source clamped.

RATE BIT/S	LENGTH(km) FOR GIVEN NO OF TRIBS 1	2	3	4	5	6	7	8
9600	1.1	1.1	1.1	1.1	1.1	1.1	.50	0
4800	2.5	2.5	2.5	2.5	2.4	1.4	.50	0
2400	4.4	4.4	4.2	3.3	2.4	1.4	.50	0
1200	6.1	5.2	4.2	3.3	2.4	1.4	.50	0
600	6.1	5.2	4.2	3.3	2.4	1.4	.50	0
300	6.1	5.2	4.2	3.3	2.4	1.4	.50	0
110	6.1	5.2	4.2	3.3	2.4	1.4	.50	0

(h) Twin paris, 30V supply, current souce clamped

Rate bit/s	Length(km) for given number of tributaries 1	2	3	4	5	6	7	8
9600	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1
4800	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
2400	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4
1200	7.0	7.0	7.0	7.0	7.0	7.0	6.1	5.1
600	10	10	9.9	8.9	8.0	7.0	6.1	5.1
300	12	11	9.9	8.9	8.0	7.0	6.1	5.1
110	12	11	9.9	8.9	8.0	7.0	6.1	5.1

(i) Single pair, 15V supply,
8925 unit(s) used in link,
current source clamped.

RATE BIT/S	LENGTH(km) FOR GIVEN NO OF TRIBS 1	2	3	4	5	6	7	8
9600	.04	.04	.04	0	0	0	0	0
4800	2.0	2.0	1.4	0	0	0	0	0
2400	4.1	3.0	1.4	0	0	0	0	0
1200	4.6	3.0	1.4	0	0	0	0	0
600	4.6	3.0	1.4	0	0	0	0	0
300	4.6	3.0	1.4	0	0	0	0	0
110	4.6	3.0	1.4	0	0	0	0	0

(j) Single pair, 30V supply,
8925 unit(s) used in link,
current source clamped.

RATE BIT/S	LENGTH(km) FOR GIVEN NO OF TRIBS 1	2	3	4	5	6	7	8
9600	.04	.04	.04	.04	.04	.04	.04	.04
4800	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.1
2400	4.1	4.1	4.1	4.1	4.1	4.1	2.7	1.1
1200	6.8	6.8	6.8	6.8	5.8	4.2	2.7	1.1
600	10	10	8.9	7.4	5.8	4.2	2.7	1.1
300	12	10	8.9	7.4	5.8	4.2	2.7	1.1
110	12	10	8.9	7.4	5.8	4.2	2.7	1.1

(k) Single pair, 15V supply,
no 8925 units anywhere in link,
current source clamped.

RATE BIT/S	LENGTH(km) FOR GIVEN NO OF TRIBS 1	2	3	4	5	6	7	8
9600	1.1	1.1	1.1	0	0	0	0	0
4800	2.5	2.5	1.4	0	0	0	0	0
2400	4.4	3.0	1.4	0	0	0	0	0
1200	4.6	3.0	1.4	0	0	0	0	0
600	4.6	3.0	1.4	0	0	0	0	0
300	4.6	3.0	1.4	0	0	0	0	0
110	4.6	3.0	1.4	0	0	0	0	0

(l) Single pair, 30V supply,
no 8925 units anywhere inlink,
current source clamped.

RATE BIT/S	LENGTH(km) FOR GIVEN NO OF TRIBS 1	2	3	4	5	6	7	8
9600	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1
4800	2.5	2.5	2.5	2.5	2.5	2.5	2.5	1.1
2400	4.4	4.4	4.4	4.4	4.4	4.2	2.7	1.1
1200	7.0	7.0	7.0	7.0	5.8	4.2	2.7	1.1
600	10	10	8.9	7.4	5.8	4.2	2.7	1.1
300	12	10	8.9	7.4	5.8	4.2	2.7	1.1
110	12	10	8.9	7.4	5.8	4.2	2.7	1.1

4.3 Limits for any cable

(a) Voltage limited lengths

Single Pair 15V supply: $L = \dfrac{245 - 62.5T}{R}$

Single Pair 30V supply: $L = \dfrac{545 - 62.5T}{R}$

Twin Pairs 15V supply: $L = \dfrac{282 - 37.5(T+1.2N)}{R}$

Twin Pairs 30V supply: $L = \dfrac{507 - 37.5(T+1.2N)}{R}$

(b) Transmission rate limits
(unclamped current source)

Single pair 15V supply no 8925 units: $kb/s = \dfrac{437000}{(593-A)CL+25000}$

Single pair 15V supply with 8925 units: $kb/s = \dfrac{437000}{(593-A)CL+45000}$

Single pair 30V supply no 8925 units: $kb/s = \dfrac{437000}{(1300-A)CL+25000}$

Single pair 30V supply with 8925 units: $kb/s = \dfrac{437000}{(1300-A)CL+45000}$

Twin pairs 15V supply: $kb/s = \dfrac{437000}{(648-B)CL+25000}$

Twin pairs 30V supply: $kb/s = \dfrac{437000}{(1200-B)CL+25000}$

(c) Transmission rate limits
(clamped current source)

Single pair 15/30V supply no 8925 units: $kb/s = \dfrac{437000}{(75+0.693RL)CL+25000}$

Single pair 15/30V supply with 8925 units: $kb/s = \dfrac{437000}{(75+0.693RL)CL+45000}$

Twin pairs 15/30V supply: $kb/s = \dfrac{437000}{(75+0.693RL)CL+25000}$

KEY TO SYMBOLS

A = 105(T - M) + 1.31RL
B = 50(T - M) + 1.31RL
T = Total no. of tributaries
N = No. of tributaries with 8038 panel and absent processor module, with which link has to operate.
M = No. of bypassed tributaries with which link has to operate.
R = Cable core resistance in ohm/km.
C = Cable capacitance in nF/km measured between one core and all other cores plus screen connected in parallel.
L = Cable length in km.

5. DIAGNOSTICS

5.1 Port activity lamps

Transmit and receive indicator lamps are provided for each GEM80 serial port. The indicator circuits incorporate pulse stretchers so that a brief period of activity appears as a clearly visible flash. The presence of the pulse stretcher also means that a long continuous period of activity may have pulsating appearance.

A transmit lamp flashes only when that port attempts to transmit data, and is not affected by other switches in series in the same loop. A control port will transmit provided that its configuration data is set for it to be in use. A tributary port will transmit only if it receives a valid message containing the correct tributary address, and its configuration data is set for it to be in use.

A receive lamp flashes when current pulses of the correct polarity flow through the receive load. The lamp will flash for any activity in the loop, even if the signalling rate is incorrect.

In a twin pair cabled serial link, the transmit and receive activity lamps will flash alternately at the control port. At a multidrop tributary port there will be several receive flashes for each transmit flash.

In a single pair cabled serial link, the transmit lamp only will flash at the port which is transmitting, and the receive lamp will flash at each of the other ports.

5.2 Port failure flags

Failure flags are provided for each tributary port and for each possible route from a control port. The ports built into the processor module of a standard GEM80 controller use bits in the alarm summary location in the fault table (F9 for 100/235 etc, F41 for 250).

These flags are intended for inclusion in the user program to allow appropriate action to be taken in the event of loss of communication along a serial link. Typical actions may be to give an alarm to the plant operator, to adopt a modified control strategy, or to effect a controlled plant shut down.

To avoid nuisance trips due to occasional noise spikes, the failure flags are set only when a set of automatic retries have been exhausted. In considering the safety aspects the user should bear in mind that the retries take a finite time, and there will be a significant delay before a failure can be reported, even if it is a catastrophic fault such as a severed cable.

5.3 Control port failure

A control port will automatically attempt to establish communication immediately after power up. It will transmit its first message and wait for a reply. After a timeout period which varies according to the chosen signalling rate, it will try again, up to a total of 3 retries. If all fail, then the failure flag is set, and the port either steps onto the next route (if multidrop) or starts again with a new set of output data. When a multidrop control port finds a failed tributary, it waits for 7 complete scans of all the healthy tributaries before retrying the failed one. If a multidrop control port finds several failed tributaries, it will try only one of the failed routes during any one scan of the healthy ones. The failure flag will be reset immediately that a valid reply is received.

Because of the cumulative time delays it is recommended that the user should not operate serial links with several tributaries out of action. It would be preferable to alter the configuration data at the control port to communicate only with the healthy tributaries.

5.4 Tributary port failure

A tributary port transmits data only when it has received a valid message. It can deduce failure only by the absence of received messages containing the correct tributary address. The port failure flag will be set if ever there is a gap longer than 21 seconds after the reception of the last valid message. The flag will be reset immediately on reception of a valid message.

5.5 Serial link statistics

The use of standard GEM80 ESP protocol ensures a very high confidence that any data conveyed via a serial link will be accurate, and that recovery from any corruption will be automatic and invisible to the user. However, it is not advisable to operate a serial link with a continuous high level of failures and retries, because of the delays associated with timeout periods and retries. Furthermore, if a message is corrupted by more than one burst of noise, there is a small statistical probability that one valid message could be transformed into a different but apparently valid message i.e. there could be an undetected failure allowing wrong data to get through.

To allow the user to assess the reliability of a GEM80 link, serial link performance statistics are provided at every control port. The statistics provided are:-

(a) Quantity of link requests.
(b) Quantity of link attempts.
(c) Quantities of failures in various categories.

A link request arises each time a new set of data is obtained from the data tables for transmission. If failures occur there may be up to 4 attempts at communication for the one set of data. The difference between the quantities of requests and attempts is the quantity of failures. The accumulated serial link statistics are cleared to zero on a power up at the control port. It is quite normal for a few link failures to occur during start up, particularly if different ports are switched on at different instants in time. Thereafter link failures should be a very small proportion of link attempts. It is quite common for GEM80 links to operate for days on end with no failures at all. If failures are due to noise pick-up then it is recommended that the user should assess the maximum tolerable level of detected failures by relating it to the consequences of undetected failures, which will be statistically less than 1 in 65000. For example 20 detected failures per day would correspond (worst case) to 1 undetected failure every 10 years. Operation at much higher levels of failure is sometimes inevitable e.g. due to noise on telephone or radio links, but the user should then build in protection against undetected failures, by incorporating duplication, checking and acknowledgement within the data transferred.

It is recommended that serial link statistics should be inspected during commissioning, and every few months thereafter. A sudden increase in the level of failures may give early warning of hardware failure, or indicate an increase in noise pick-up due to changes in the plant cabling. The statistics thus offer the opportunity for preventive maintenance, which can avoid plant downtime.

6. PRINTER PORT

6.1 Available facilities

Early GEM80 controllers (130-6K, 221, 231, 241) had a printer port which was suitable for data output only, and only as complete lines. Later controllers (130-12K, 225, 235, 245, etc.) include a special character (@3) for output of part lines, and include a single character input facility for serial keyboards. The 250 series offers the ability to have more than one printer port, and includes improved printer special functions, and a buffered multi-character input facility via a printer port.

6.2 Printer output

When a port is used for printer output, the data is transferred directly from the program rungs to a printer buffer, without using the serial output data table.

The special functions used for printer output are fully described in their software data sheets. Functions S22 WRITEXT and S23 WRINUM are used in 130 and 225/235/245 type controllers. The 250 series uses S38 PRITEXT, T38 PRINT and T39 CHARIN. The user program normally includes interlocks with E table flag(s) which give indication of how full the printer buffer is.

Normally the printer buffer outputs complete lines only; the inclusion of character ETX (code @3) in a WRITEXT, PRINT or PRITEXT message causes the preceeding characters to be output even if the line is incomplete. This is typically used to produce an interactive display on a serial VDU, which builds up character by character as the user enters data. The technique may not be applicable to a printer, because many printers include internal buffering which prevents any printing until a whole line has been received.

Early GEM80 controllers (130/235 etc) used a fixed character format for printer output:- 1 start bit, 7 character bits (ASCII code), even parity bit, 2 stop bits. The 250 series has user selected options of 7 character bits plus odd or even parity, or 8 character bits without parity.

6.3 Keyboard input

(a) Early controllers 130/235 etc

The keyboard input facility uses the lowest location in the serial input data table area (usually J0) to receive characters from a serial keyboard. The data is the 7 bit ASCII code for the received character, with any parity bit ignored and discarded.

The facility is suitable only for single characters, because each received character simply overwrites the previous one. A series of characters can be accepted, but only if they arrive at a rate not exceeding one per scan of the user program.

It is recommended that the user program should set the receiving location to zero every time a character is received, so that two consecutive identical characters can be distinguished.

A typical user program would be:-

```
|                                    |
+-<AND>--------------------------OBEY-+
   J0                            BLOCK

*********** START OF BLOCK *********  |
|                                     |
| Rungs to receive and assemble input |
| data                                |
|                                     |
+-<AND>--------------------------<OUT>+
|   0                              J0 |
|                                     |
+  ********* END OF BLOCK **********  +
```

Typical rungs to reflect keyboard input to the printer output would be:-

```
|                                     |
+-<AND>---------------------------OBEY-+
    J0                            BLOCK

*********** START OF BLOCK *********  |
|                                     |
+-<AND>--------------------------<OUT>+
|   4                             G10 |
|                                     |
+-<AND>--------------------------<OUT>+
|   J0                            G11 |
|                                     |
+-<AND>--------------------------<OUT>+
|   3                             G12 |
|         WRITEXT                     |
+-<AND>---SPEC.----VALUE---------<OUT>+
|   1     S22        G10         F100|
|                                     |
+-<AND>--------------------------<OUT>+
|   0                              J0 |
|                                     |
+  ********* END OF BLOCK *********   +
```

G10 contains the message length, which is 4 because of the NUL bytes in the upper halves of G10 and G11, the character in the lower half of G11, and the ETX character in G12 which forces the message to be output. Only a single character is actually transmitted to the printer.

(b) 250 series controllers

Serial input via the printer port of a 250 series controller is automatically buffered. Alternative modes (direct and terminal) are available, and give the option of interactive operator interface with auto-echo and line-editing without user-programming.

Serial input data is made available to the user program by the T39 CHARIN special function.

The received data character format is either 7 or 8 data bits, according to the option selected for the printer port. If a parity option is selected, then code ∂FF is substituted for any character received with the wrong parity bit.

Further details of the printer port facilities of the 250 series are contained in the 250 series user information leaflet.

6.4 Typical circuits

Fig.14 shows typical circuits for a printer port. Unlike control and tributary ports on GEM80 links, a single pair cable cannot normally be used for both directions of information flow. A 2 wire arrangement can be used only if the application does not require simultaneous output to the printer and input from the keyboard.

If desired several printers and/or VDUs may be connected in series. Sometimes it may be desirable to have different printer ports connected to the same printer, in which case the transmit switches may be connected in series. The user would have to arrange that only one printer port could produce an output at any one time. The cable length limits quoted in section 4.2 for twin pair cables will apply if the maximum volt drop of each load is 1.5V.

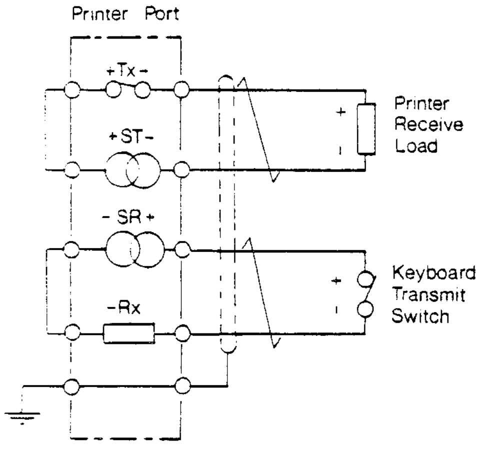


Fig.14 Typical circuit for printer port

7. PROTOCOL AND MESSAGE STRUCTURE

7.1 Introduction to ESP

Extended Simple Protocol (ESP) is the protocol used for asynchronous serial communication between GEM80 controllers, and between a programming unit and the programming port of a GEM80 processor.

The information which follows is intended to help users who wish to implement ESP themselves. No knowledge of ESP is normally required for straightforward application of serial links between GEM80 controllers.

7.2 ESP Definition

The protocol uses asynchronous communication with 1 start bit, 8 data bits and 1 stop bit. The data has no defined parity as of right, although the information it contains may be so defined.

All communication is between a control station and one or more tributary stations, all transmissions being initiated by the control station. A tributary station may not transmit except by invitation of the control station and may not transmit to other than the control station. Although separate transmission channels are provided for the two directions, normally only one station transmits at a time. However a tributary station does not have to wait until the end of a received message to send a negative acknowledgement should it detect an error. Additionally certain corruption situations may cause inadvertent simultaneous transmission.

The control characters used within the protocol are chosen from the ISO-7-UK set with the most significant bit set to zero.

Data transparency is achieved by preceding any significant character (i.e. STX, ETX, ETB, EOT, DLE or ENQ) by a DLE to indicate that the following character is not to be treated as a control character. The insertion of DLE's prior to transmission and their deletion on reception is done by the protocol handling programs and is invisible to the user.

A message from the control station has the following format:-

STX ADDR DATA TERM CRC

STX — Control character signifying start of message.

ADDR — The one byte address of the tributary station for which the message is intended. An address of 00 is defined for point to point working, and FF hex for a global address recognized by all tributaries. Standard GEM80 controllers use the most significant 4 bits for address and the least significant 4 bits for message type, so ADDR byte 0x is defined for point to point working and Fx hex for global address.
In the future it is expected that an extended address range option will be introduced, allowing more of the address byte to be used for tributary addresses.

TERM — One of two characters ETX or ETB. These are used alternately to each individual tributary.

CRC — A 2 byte cyclic redundancy check code calculated using the polynomial X16+X15+X2+1 using all bytes (including the DLE's added for data transparency) following the STX up to and including the TERM. CRC example for message of STX, NULL, ETX is 40, 01 (HEX).

The addressed tributary, and only the addressed tributary, may respond in one of three ways.

a) It may respond with a message in the same format as that received, using the same terminating character and containing its own address in the ADDR byte.

b) It may respond with a positive acknowledgement (ACK) in the form:-

ACK TERM

The TERM character being the same as that received.

c) It may respond with a negative acknowledgement (NAK) in the form:-

NAK

Where the address of the received message is the global address the tributary will act on the message as if it were for itself but the response will be suppressed.

Reception of a correctly formatted message or ACK by the control station is deemed to complete the exchange. Should the control station detect a hardware failure or timeout or receive either a corrupt message or a NAK then a failure is deemed to have occurred. The program will attempt to recover from this situation up to five times and only if this is unsuccessful is a failure returned to the user. Fewer retries may be used at the implementer's discretion, 3 is used for most GEM80 controllers.

In order correctly to recover from corruption it is necessary to discover whether the failure happened on the outgoing message or on the reply. This information is used to avoid duplication or omission of one message of a string of messages. The control station requests retransmission of the last reply by means of the enquiry message:-

ENQ ADDR

The ADDR may not be the global address.

By inspection of the terminating character the control station can determine whether it now has a correct response or whether it needs to re-transmit the original message.

In the case of a reply NAK, the control station can surmise that corruption happened on the original transmission and initiate an immediate re-transmission.

If a transmitting station wishes to terminate a message prematurely then it should send:-

EOT EOT

At present the control ports built into standard GEM80 controllers do not make use of this abort sequence, but triburary ports will recognize it.

A receiving station sufficiently identifies an aborted message by the recognition of the single control character EOT.

The recommended timeout periods vary with transmission rate:-

Bit/s	Timeout	Bit/s	Timeout
9600	0.75s	600	2.75
4800	1.0s	300	5.0
2400	1.25s	110	13.75
1200	1.75s		

Timing commences at the end of message transmission from the control port, and a retry will be initiated if a complete reply message has not been received before a timeout occurs.

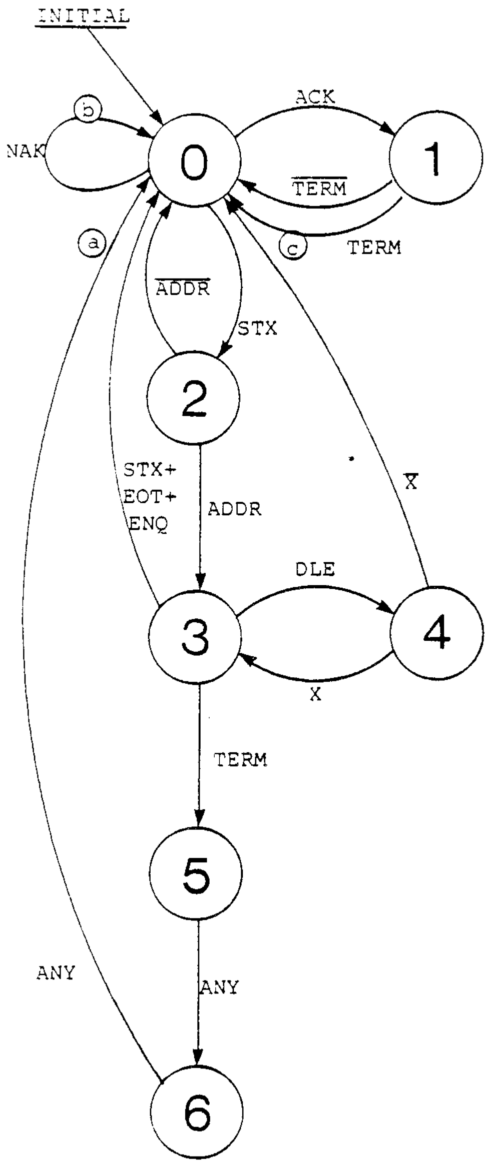
The control ports provided in standard GEM80 controllers for serial links between GEM80 systems use the times recommended above with an accuracy of +0s,-0.25s. This guarantees at least 0.25s for the tributary to start replying, plus the transmission time for a full length (32 word) message with every byte a control character requiring stuffing.

The GEM80/250 series has an option (the user-control mode) for delaying the transmission of a reply message under the control of the user program. To cater with the extra turn round delays, the control port of a 250 series controller has the option of a doubled timeout period.

MINIGEM incorporates a similar user-control option, and has the option of specifying in the user program the timeout period to be used.

The timeout period implemented for the programming unit control port operating at 9600 bit/s is 1.0s, which allows for a significant amount of processing at the controller before a reply is initiated.

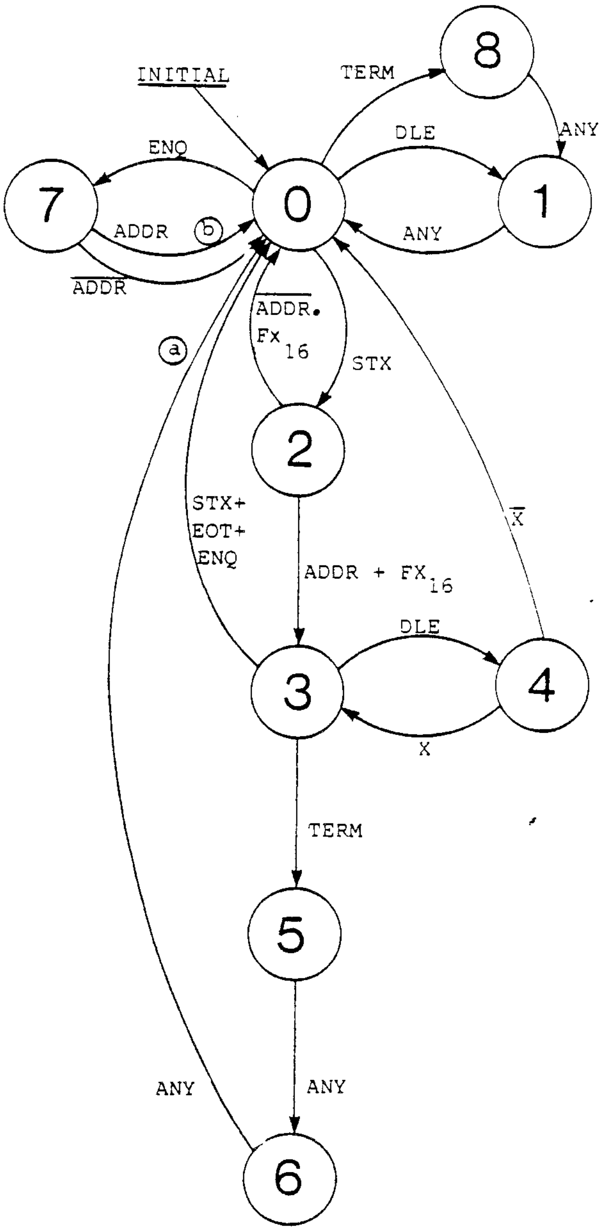
Fig.15 illustrates the logic for message reception in state diagram form. Only the sequence is defined, because details such as whether DLE's are stripped as received or as a subsequent operation depends on the implementation.



X = STX+ETX+ETB+DLE+EOT+ENQ

Transition (a) signifies end of message.
Transition (b) signifies NAK reply.
Transition (c) signifies ACK reply.

Fig.15a Control state diagram for message reception



X = STX+ETX+ETB+DLE+EOT+ENQ

Transition (a) signifies end of message.
Transition (b) signifies request for retransmit.

Fig.15b Tributary state diagram for message reception

7.3 J/K table exchange messages

The usual form of data exchange between two GEM80 controllers is J/K table exchange, as described in section 1.3.

The message type associated with J/K table exchange is "3", and the data transmitted by the control port includes the letters "J" and "K" in ASCII form.

Note that the letters J and K are retained for use by the fast I/O serial communications module 8845-4101, although the source and destination tables are then the C and D tables.

All messages comply with ESP:-

STX ADDR DATA TERM CRC
with DLE preceeding any data byte which happens to be a control character.

Control station output:-

ADDR Most significant 4 bits are tributary address. For standard GEM80 controllers the range is limited to 0 to 7. Least significant 4 bits are message type which is 3 in binary.

DATA 1st two bytes are K and J in ASCII code (4B,4A hex).
3rd byte is least significant byte of data from lowest K location.
4th byte is most significant byte from lowest K location.
5th and 6th bytes are data from next K location.....etc.
If no K locations are transmitted, then K is the only byte of DATA.

Tributary station output:-

ADDR Most significant 4 bits are tributary address as received (limited to range 0 to 7 for standard GEM80 controllers). Least significant 4 bits are message type (3 in binary).

DATA 1st byte is least significant byte of data from lowest K location.
2nd byte is most significant byte from lowest K location.
3rd and 4th bytes are data from next K location....etc.

7.4 Programming port messages

This section describes the standard set of programming messages implemented in all GEM80 controllers and GEM80 programming units.

All messages comply with ESP:-

STX ADDR DATA TERM CRC

For point-to-point serial link to front panel programming socket of any GEM80 controller, the ADDR byte is always zero. For remote programming, which can use a multidrop serial link, the ADDR byte is hex 00 to E0 for tributary addresses 0 to 14 respectively.

The standard messages are transmitted as printable characters, data and addresses being translated to the equivalent hex string where appropriate. For example table location G1025 (0401 hex) is transmitted as the ASCII codes for letter G and numerals 0,4,0,1. The resulting hex string is 47,30,34,30,31. Similarly instruction number 1025 (or a value of 1025 for the contents of a data table location) would be transmitted as hex 30,34,30,31.

The restriction to printing characters means that ESP control characters cannot arise in any of these messages, and byte stuffing is never needed. Note that a different (binary) representation is used for block messages (see next section).

Control messages use an initial upper case letter C followed by another upper case letter, both in ASCII code:-

DATA for control messages	Reply
CC - Clears store	ACK
CH - Halts user program	status
CM - Queries identity	identity
CN - Sets test flag to normal	status
CQ - Queries status	status
CR - Runs user program, or re-compiles if on-line programming available.	status
CS - Single cycle of user program	ACK
CT - Sets test flag to test	status

The status reply is a pair of ASCII characters, H or R or C (halt or run or changed), followed by T or N (test or normal), followed by an optional text string for display as a diagnostic message on the programmer screen. The "changed" status arises only in controllers where the source program can be changed on line, giving rise to the possibility of the running program being different to that viewed via the programming unit.

The CM message is not implemented on the early range of 100 and 235 controllers, but is implemented in BASIC and COMMUNE languages, and in the 250 series and MINIGEM. The reply comprises a text string describing the product, followed by an optional further line to give instructions or prompts to the user.

Programming and monitoring messages use an initial upper case letter in ASCII code to indicate the type of message:-

DATA for programming and monitoring messages	Reply
Daaaa - Deletes instr. no. "a".	ACK
Gaaaa - Gets instr. no. "a".	iiiiiii
Iaaaa - Inserts null instr. at instr. no. "a".	ACK
Paaaaiiiiiii - Puts instr. "i" into instr. no. "a".	ACK
Rfaaaa - Reads contents of data table letter "f" location no. "a".	@dddd
Wfaaaa@dddd - Writes data "d" into data table letter "f" location no. "a".	ACK

The quantity of characters in each message is indicated by the number of letters shown above.

In all cases a context check is done. If this fails a reply of ASCII character "?" is generated. For example the "?" reply will be given if a data table address is not valid for the controller, or program alteration is attempted in run status for a controller with no facility for on-line program changes.

Instruction numbers, data table location numbers, and data table contents are transmitted as four ASCII characters representing the number in four digit hexadecimal form, most significant digit first.

Data table letters are transmitted as a single ASCII character (upper case). ASCII character "@" is used to indicate a numeric value.

Ladder diagram instructions are transmitted as seven ASCII characters:-

f1, f2, p, h1, h2, h3, h4

f1, f2 - Two ASCII characters representing the type of instruction as a two digit hexadecimal number, most significant digit first.

p - One ASCII character representing the data table letter, or ASCII "@" sign if the operation relates to a constant value.

h1,h2,h3,h4 - Four ASCII characters representing the table offset or constant value in four digit hexadecimal form, most significant digit first.

HEX CODE	TYPE OF INSTRUCTION
04	ADD constant
14	ADD table location
44	ADD on branch merge
08	AND decimal constant
0E	AND decimal constant, from left rail
09	AND HEX constant
0F	AND HEX constant, from left rail
18	AND table location
1E	AND table location, from left rail
48	AND on branch merge
4B	Branch merge
4A	Branch return, end of upper branch
49	Branch split, start of upper branch
12	COUNTER
11	DELAY
19	SEQUENCER
17	SPECIAL FUNCTION
4F	INVERT
A*	-]/[- * = bit no 0 to F
C*	-]/[- from left rail, * = bit no
8*	-] [- * = bit no 0 to F
D*	-] [- from left rail, * = bit no
E*	COIL output, * = bit number 0 to F
0D	OR on constant
1D	OR on table location
4D	OR on branch merge
1C	OUT
40	START BLOCK
41	END BLOCK
05	SUBTRACT constant
15	SUBTRACT table location
45	SUBTRACT on branch merge
00	VALUE decimal constant
01	VALUE hex constant
10	VALUE on table location
03	XOR on hex constant
13	XOR on table location
43	XOR on branch merge

In general edit mode (as used for GEM80 video, BASIC and COMMUNE languages, and 250 message editor), there is a continuous exchange of messages between the programming unit and the processor module.

The programming unit sends either an empty message (ESP message with no DATA bytes), or a message containing a single ASCII character corresponding to the key pressed on the keyboard.

The processor replies either with an ACK message, or with a string of up to 90 printable ASCII characters for display on the screen.

Load/dump of video formats uses exactly the same messages as the preset data part of a ladder program.

BASIC and COMMUNE operate within general edit mode for tape load/dump/verify, and for program listing to screen/printer.

If a BASIC/COMMUNE program is running, then the processor produces an ACK reply message to any message other than that produced by pressing the "escape" key. "Escape" (1B hex) causes program execution to halt, and enables subsequent messages to be interpreted as programming commands e.g. L,I,S,T,(CR) to list program, L,O,A,D,(CR) to load a program, R,U,N,(CR) to command run.

During listing or tape dumping, the processor module outputs the program as a string of printable characters, one line per message. The programming unit transmits an empty message when it is ready for the next line.

During tape loading or verification, the programming unit transmits the program as a string of printable characters, one line per message, each line preceeded by ASCII letter L as the first character of the message. The normal reply from the processer is "ACK"; a "?" reply indicates a rejected line. End of program is indicated by a control message, consisting of ASCII letters CZ, transmitted by the programming unit.

In the messages from the processor, the following hex codes are defined as control characters, conveying control commands to the programming unit.

F0 - Exit from general edit mode, and return to initial entry selection.
0E - Start printing. Subsequent chars output to screen and printer port.
0F - End of print/load/dump/verify.
19 - Start tape loading.
1A - Start tape dumping.
1C - Start tape verification.

7.5 Block messages

Block messages were introduced to the GEM80 family in late 1983. They are provided in particular products as an addition to the standard messages in the preceding section.

The block messages can only be utilised when both the controller and the programming unit include the new messages. If the new messages are not available, then the old messages will automatically be adopted by the programming unit.

The block messages give a considerable increase in communication efficiency, allowing the response of the programming unit to appear faster, and enabling faster program load/dump.

Additional control messages:-

CF - Asks the controller to indicate what facilities may be used by the programmer. Controller reply is "?" for older controllers, or a string of three ASCII characters for recent controllers. The first character is "O" (capital letter O) indicating that on-line program changes are permitted, the 2nd character is "B" indicating that block messages are available (see below), and the 3rd character is "E" indicating that general edit mode is available. If a facility is not available, then ASCII "." (full stop) is substituted for the appropriate letter(s). The message may be truncated after the last available facility. It is expected that future facilities will be indicated by extending the reply to include further options.

CE - Finds the Extent of the user program and P table. The reply is Li, Lp, where Li the number of the last instruction in the user program, and Lp is the highest non-zero P table location. Each quantity is a 16 bit binary number in 2s complement form, transmitted least significant byte first. -1 indicates empty.

Stan- Reads the contents of n data table locations in a contiguous block. "t" is ASCII character for table letter, "a" is starting location number as a 16 bit binary number, transmitted least significant byte first, and "n" the quantity of locations to be read as an 8 bit binary number in range 1 to 32. The reply is t(a),t(a+1)...t(a+m), where "t(a)" is contents of the starting location, and m<n if end of table is encountered. The contents of each location is a 16 bit binary number is 2s complement form, least significant byte transmitted first. The reply is ASCII character "?" if t(a) is off end of table.

Xtan d(0),d(1)...d(n-1)- Writes the "n" values "d(0)" to "d(n-1)" into a contiguous block of data table locations. "t" is ASCII character for table letter, "a" is starting location number as 16 bit binary number, least significant byte transmitted first, and "n" is an

8 bit binary number in range 1 to 32. Each value is 16 bit binary number in 2s complement form, least significant byte transmitted first. The reply is ASCII "ACK" if all values are accepted, ASCII "?" if message rejected (in which case no values are written into table).

Jin - Inserts "n" NULL instructions starting at instruction no."i". "i" is 16 bit binary number, least significant byte transmitted first. "n" is 8 bit unsigned binary number in range 1 to 255. The reply is ASCII "ACK" for success, or ASCII "?" for failure (in which case no NULLs are inserted).

Ein - Deletes "n" instructions starting at instruction no. "i". "i" is 16 bit binary number, least significant byte transmitted first. "n" is 8 bit unsigned binary number in range 1 to 255. The reply is ASCII "ACK" for success, or ASCII "?" for failure (in which case no instructions are deleted).

Qin j(0),j(1)...j(n-1) - Writes the "n" instructions "j(0)" to "j(n-1)" into store starting at instruction no. "i". "i" is 16 bit binary no. least significant byte transmitted first. "n" is 8 bit number in range 1 to 16. Each instruction consists of 4 bytes, first an 8 binary number for the instruction type, next the ASCII character for table letter or "@" indicating a value, next a 16 bit binary number representing the table location number or numeric value, least significant byte transmitted first. The reply is ASCII "ACK" for success, or ASCII "?" for failure (in which case no instructions are written).

Hin - Reads the "n" instructions starting at instruction no. "i". "i" is 16 bit binary number, least significant byte transmitted first. "n" is 8 bit binary number in range 1 to 16. The reply is j(i), j(i+1)...j(i+n) for success, or ASCII "?" for failure. Each instruction consists of 4 bytes as defined above.

7.6 Program load/dump procedures

The user can program his own computer to load and dump programs from GEM80 systems. For controllers released to end '83, a point-to-point twin pair 20mA serial link is required to the programming port of the appropriate processor module, operating at 9600 bit/s, and using ESP protocol and the GEM80 messages described in section 7.4.

GEM80/250 series and MINIGEM controllers include the facility for programming messages to be accepted via the user's serial ports. This allows the user to construct a multidrop serial link from his computer to several controllers, and to operate the serial link at a signalling rate chosen to suit the cable lengths involved.

The GEM80/250 series includes block messages which may be used for programming and monitoring messages from a supervisory computer.

The following procedures outline the sequences which may be performed by a computer.

(a) To dump ladder program:-

Use "get" message to read instructions sequentially from number zero until end of program is indicated by two consecutive NULL instructions (30,30,40, 30,30,30,30 hex).
Use "read" message to read location V32, which contains number of highest location in P table.
Use "read" messages to read contents of P table sequentially from P0 to highest location.
If implemented, the "CE" message may be used to find the size of the user program instructions and P table, and block messages may be used to increase the efficiency of data transfer.

(b) To load ladder program:-

When safe to do so, use "halt" message to halt controller.
Use "clear store" message to clear all instructions and P table.
Use "read" message to check contents of location F1 are zero. If not, switch power off/on to controller.
Use "put" messages to load instructions sequentially from n mber zero to end of program.
Use "write" messages to load P table locations sequentially from P0. Only non-zero locations need be loaded.
When it is safe to do so, use "run" message to recompute program CRC in controller, and run program.
If implemented, block messages may be used to increase the efficiency of data transfer.

(c) To dump video formats:-

If using paged video, use "write" message to load location P24 to set page number to be dumped:

Page	Hex	Page	Hex	Page	Hex
0	0000	3	1800	6	2400
1	1000	4	1C00	7	2800
2	1400	5	2000	8	2C00

Use "read" message to read location V32 which contains number of highest location in P table.
Use "read" messages to read contents of P table sequentially from P0 to highest location.

(d) To load video formats:-

Use "write" messages to load P table locations sequentially from P0 to end of program.

(e) To dump BASIC/COMMUNE program:-

When safe to do so, use "halt" message to terminate program execution.
Use messages containing individual characters to transmit L,I,S,T,(CR).
Use empty message to request next line until the processor indicates end of program by empty reply message.
When safe to do so, use "run" message to re-start program execution.

(f) To load BASIC/COMMUNE program:-

At various points in this sequence the processor module transmits text strings intended for operator display. It may be appropriate for some of them to be displayed on the user's computer console.
When safe to do so, use "halt" message to terminate program execution.
Use "read" message to check contents of location F1 are zero. If not, use messages containing individual characters to transmit N,E,W,(CR), and switch power off/on to controller.
Use messages containing individual messages to transmit L,O,A,D,(CR).
Transmit empty messages until processor replies with message "DO YOU WISH TO CLEAR THE EXISTING PROGRAM (CR) PRESS Y OR N -". Transmit message containing character Y.
Transmit empty messages until processor replies with message "PRESS SPACE BAR TO CONTINUE". Transmit message containing space character (20 hex).
Transmit program, one line per message, with each line preceeded by letter L as first character in message data.
Transmit control message CZ to indicate end of program.
When it is safe to do so, use "run" message to start program execution.

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