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                   JANUS Interface Specifications

                 (Symmetrical, 1822-like Interface)

1. INTRODUCTION
1.1. Motivation

A need arose in the Packet Radio project for specification of an
interface between Packet Radio units and other equipment. This paper is
to meet BBN's responsibility to supply that specification. It is our
hope that it will find application in other areas as well.

1.2. Historical Relationship to 1822

The ARPANET employs a network of switching nodes, called IMPs, to
provide interconnection among user equipment, called hosts. A uniform
means of connecting a host to an IMP is specified in BBN Report Number
1822. Consequently, this interface has become known as an 1822
interface.

As the need to interconnect new types of devices has grown, it has
become attractive to implement an 1822-like interface on each end of
pairs of devices which are to communicate. The devices are then
connected electrically, and communication can take place in spite of
differences in processing speed, word length, signal levels and so forth
in the two devices. A part of Report 1822 reads as follows.

    "The technique of transferring information between the Host and the
    IMP is identical in each direction; we will, therefore, refer to the
    sender and the receiver without specifying the Host or IMP
    explicitly."
    [BBN Report Number 1822, 12/75 revision, page 4-2.]

Unfortunately, Report 1822 does not specify a completely symmetrical
interface. Although there is a high degree of symmetry, some aspects
are peculiar to the IMP side and some to the host side. Therefore, two
interfaces constructed to connect to IMPs may not function connected to
each other. In what follows, the unsymmetrical aspects are respecified
in a way which will accomplish full interchangeability.

The interface specified here is called the JANUS interface, to
distinguish it from the Report 1822 interface.

1.3. Terminology

The terms, "IMP" and "host," are not relevant in the present context.
Sections of Report 1822 such as Appendix B are conveniently
re-interpreted by substituting "foreign interface" and "home interface,"
respectively.

2. SPECIFICATIONS

Report 1822 addresses two aspects of the connection of a host to the
ARPANET, the hardware requirements and the software protocols. Since
the JANUS interface will typically be used in applications other than
connection to the ARPANET, the higher level software protocols are
beyond the scope of this paper. They are properly addressed by
documentation specific to each application. Concern here is only for
electrical specification of the JANUS interface. The various areas
which differ from Report 1822 are as follows.

2.1. Low-level Protocol

Certain aspects of the JANUS interface and its operation may be
implemented in hardware, software of a mixture of the two. We refer to
these aspects as "low-level protocol." They are to be distinguished
from such "high-level protocol" aspects as header definitions and data
formats.

2.1.1. Padding

Requirement:
Received messages are padded out to a full word (of the home device's
size), if necessary, with zeros only.

Discussion:
A one-bit to mark the end of received data, as IMPs employ, is NOT used.
The mark bit has not proved very useful, although the ARPANET IMPs do
use it to generate the message length field in the new format header.
Rather, counts at one or another level of protocol are generally used,
so the complication of a mark bit can be eliminated. It is the author's
impression that the ARPANET will not implement this aspect of
symmetrical interfaces, so hosts communicating through the ARPANET will
continue to see the marker one-bit appended by the source IMP regardless
of whether the hosts have 1822 or JANUS interfaces.

2.1.2. Message Length

Requirement:
A JANUS interface must accept messages up to and including 8160 bits
long.

Exception:
If the interface is absolutely never intended for use in
ARPANET-compatible applications, this requirement may be relaxed in any
of three ways. A smaller maximum length may be implemented; a larger
maximum lengthbe implemented; or the maximum length may be so large as
to be in practice infinite.

Discussion:
A JANUS interface may discard messages longer than 8160 bits when used
with the ARPANET. This constraint can be enforced in software rather
than in hardware, if desired.

2.1.3. Four-way Handshake

Requirement:
The interface must use the four-way handshake. That is, the receiver
must wait until the incoming There's-Your-Bit drops before turning on
Ready-For-Next-Bit.

Discussion:
The two-way handshake, presented as an option in Report 1822, must not
be used. Experience has shown that it is vulnerable to various
failures. First, if the off period in RFNB is not seen by the sender
(due to noise or its being too short), a deadlock occurs and no more
data is transferred. Second, a two-way receiver cannot talk with a
strictly four-way sender, since the sender's next assertion of TYB may
depend on seeing the RFNB transition to on. And third, the two-way
handshake is overly sensitive to transitions, and may be activated by
noise pulses. Transitions in the two-way handshake may be missed
altogether in a sender implementation which samples the RFNB line only
at certain intervals. The superiority of the more positive four-way
handshake is important in applications where neither of the
communicating interfaces is necessarily constructed to particular
standards.

2.1.4. Contact Bounce

Requirement:
Each interface, considered together with the software driving it, must
prevent data from flowing across the interface in either direction while
its Ready relay contacts may be bouncing. Thus, for 1/10 second after
raising Ready, the outgoing signals There's-Your-Bit and
Ready-For-Next-Bit must not be asserted.

Discussion:
This may be accomplished either in hardware or software, as discussed in
Report 1822 section B.3. The delay of 1/10 second is specified here to
resolve an ambiguity in Report 1822, concerning whether a shorter delay
was acceptable if the relay was known to solidly finish closing sooner.

Report 1822 specified a 1/2 second delay, but modern reed relays
reliably finish closing in 1/10 second.

2.1.5. RFNB, TYB Minimum Off Time

Requirement:
Ready-For-Next-Bit must be off for at least 50 nanoseconds for local
host connections, and at least 1 microsecond for distant host
connections, as seen by the receiver of the signal (who is the sender of
data). Note that this means that RFNB at the cable driver may have to
be off for somewhat longer than this minimum if deterioration of the
signal waveform along the cable is anticipated. There's-Your-Bit must
similarly be off for at least 50 nanoseconds for local host connections,
and at least 1 microsecond for distant host connections, as seen by the
receiver of the signal.

Discussion:
This extends the Report 1822 requirements for signals received by the
IMP, to both interfaces in a JANUS interface pair.

2.1.6. Deskewing

Requirement:
The outgoing data bit must be on the line and the Last-Bit level correct
at least 500 nanoseconds before the sender turns on the There's-Your-Bit
signal. The sender must turn off TYB before changing either the data or
the LB.

Discussion:
The responsibility for deskewing signals rests with the sender in each
interface. This applies the Report 1822 IMP sender behavior to each
JANUS interface as a requirement. Note that the receiver may count on
the Last-Bit signal being valid during, and only during, the assertion
of There's-Your-Bit. Specifically, Last-Bit must be asserted during
transmission of the last data bit. Report 1822 was slightly ambiguous
in this regard.

2.1.7. Transmission Order

Requirement:
"The high-order bit of each word is transmitted first." (Report 1822,
section 4.1.)

Discussion:
If a computer has addressing modes other than word addressing, such
units or bytes are not used as units of transmission by the interface.
For example, the first bit transmitted from or received into a PDP-11 is
bit 15, the leftmost bit of a 16-bit word. This is repeated here to
bring it especially to the attention of designers.

2.2. Distant Host Electrical Requirements

Discussion:
The paragraphs below specify a Distant Host option of the JANUS
interface which differs substantially from the 1822 Distant Host
interface. Several considerations prompted this change. Report 1822
specifies transformer coupling at the receiver, so requirements on
signal rise time and hold times were made. To relax these, and to
achieve greater tolerance to differences in ground potential, optical
isolators are now often used, even in 1822 interfaces. Neither the
Report 1822 Distant Host driver, nor the driver adopted for JANUS,
generate more than 1.0 volt. Commonly available optical isolators
require at least 1.1 volts to overcome their forward drop before they
will operate. Thus an optical isolator driver is needed in both the
1822 and the JANUS receivers. The ground potential difference between
the communicating interface may exceed the maximum ratings of the input
amplifier, so the input circuit must be powered from a floating power
supply. Appropriate DC-DC converters for this purpose are available at
reasonable cost.

2.2.1. DH Signal Timing

Requirement:
Receiver circuits in distant host interfaces shall be implemented with
optical isolators or other means which are not sensitive to rise and
hold times, as transformer coupling is. Therefore, the requirements for
rise and hold times on distant host signals appearing in Report 1822 are
suspended.

2.2.2. DH Signal Levels and Waveforms

Requirement:
Signal levels and waveforms at the driver and the receiver shall follow
the specifications in EIA standard RS-422. In particular, the driver
must supply a differential of at least 2 and not more than 6 volts; and
the receiver must operate correctly on as small a differential as 0.2
volts.

2.2.3. DH Electrical Isolation

Requirement:
The receiver circuit must operate correctly over a common mode voltage
range of -100 to +100 volts, and must not be permanently damaged by a
common mode voltage of from -300 to +300 volts.

Exception:
If the interface is absolutely never intended for use in an environment
where common mode voltage exceeds 7 volts in magnitude, or where the
voltage from either signal wire to the signal ground exceeds 10 volts in
magnitude, then the electrical isolation required in this paragraph may
be suspended, and the corresponding requirements of EIA specification
RS-422 applied in its place. Such an implementation is explicitly an
exceptional JANUS interface, and is not the standard JANUS interface.

Discussion:
A suggested way to achieve this isolation is an RS-422 receiver chip,
such as the Motorola MC3487 or the Advanced Micro Devices Am26LS32,
followed by an LED driver as needed, followed by an optical isolator
such as the Hewlett-Packard 5082-4360. The receivers and LED drivers
for all input lines may be powered from one source, but this power must
be floated with respect to ground of the home interface.

2.2.4. DH Cable Shield Grounding

Requirement:
At each end the cable shield in a distant host connection shall be
connected through a circuit described below to signal ground. The
circuit consists of two components connected in parallel. (1) A 100K,
1/8 watt resistor provides a path to leak off slow accumulations of
static charge.
(2) A .01 mfd, 600 V ceramic capacitor bypasses sharp noise spikes.

Exception:
In cases of severe noise, one end of the shield or the other (but not
both!) may have to be tied directly to ground, sacrificing the symmetry.

Discussion:
Grounding the cable shield only at the host end, as in Report 1822, is
undefined when the interface is symmetrical. Instead, the circuit above
will be used.

2.2.5. DH Cable

Requirement:
Cable requirements in EIA specification RS-422 must be followed with
respect to quality and electrical characteristics, and those in Report
1822 with respect to number of conductors. In particular, at least 10
twisted pairs with impedance of approximately 100 ohms must be supplied.

Discussion:
A suitable cable is PE-39, described in REA Bulletin 345-67. This cable
is similar to that mass produced for telephone cable, which is of good,
uniform quality, and readily available at reasonable cost. The cable
specified in Report 1822 is not as desirable. Note the change in
specified characteristic impedance: Report 1822 specified 120 ohms,
while the JANUS interfaces follow RS-422 with 100 ohms.

2.2.6. DH Cable Termination

Requirement:
Termination shall be as specified in RS-422, in particular at the
receiver. Termination as in Report 1822, at the driver, shall NOT be
used.

Discussion:
The source-end termination specified in Report 1822 was to eliminate the
voltage drop caused by the cable's series resistance. RS-422 explicitly
allows for this sort of signal attenuation as a part of the
specification.

3. STRONG RECOMMENDATIONS
3.1. Local Host Signal Levels

Suggested voltage levels for local host drivers and receivers are given
below. The levels below are a combination of Report 1822 levels for
316/516 and Pluribus machines. The intent here is to be compatible with
readily available TTL components. Suggested chips are the 7440 for a
driver and the 7420 for a receiver. Note that signals may go up to 6
volts, which may damage receiving circuits constructed of normal 5-volt
logic. Such receivers should have a voltage divider on their inputs.

```
    driver output voltage
        with input = 0:    -   min,  0.35 max  (0.07 typical)
        with input = 1:   3.5  min,  6.0  max  (5.0  typical)
    receiver input voltage
        to assume a binary 0:  0.6  min  (0.9  typical)
        to assume a binary 1:  2.5  max  (1.7  typical)
        maximum input rating:  6.0  max
```

Cable impedance and termination circuits are covered in Report 1822.
With properly chosen cable and well designed circuits, and with
impedances matched, local host connections may operate considerably
farther than the 30 feet given in Report 1822. Cables as long as 300
feet are in use communicating with ARPANET IMPs. For example, 300 foot
cables have worked using 7440's as drivers, standard TTL gates as
receivers, cable termination (on all signal lines) of a diode to ground
and a diode to +3 volts, and RG174/U cable. RG174/U is 50 ohm coax, and
a 100 ohm coax is preferred, to reduce ringing.
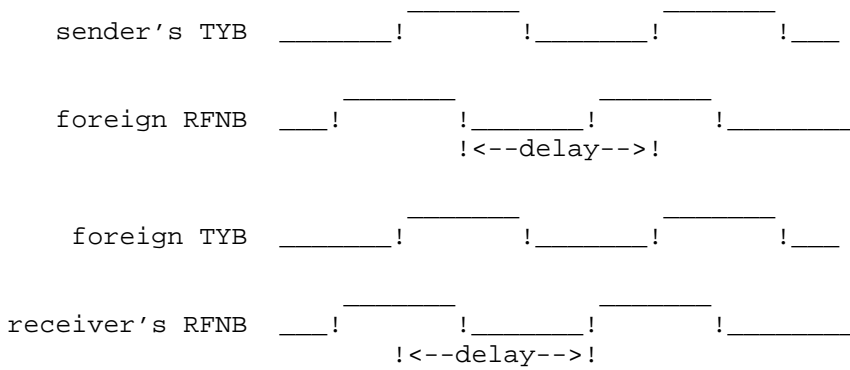
3.2. Use of the Ready Line

It is strongly recommended that the Ready Line provided by the hardware
be used by the software in a manner similar or identical to that
described in Report 1822. Report 1822 sections 3.2, 4.4 and Appendix B
especially bear on this topic. In particular, the software design
should provide for the following:

   (1) A ready indicator (relay) which tells the foreign interface that
       the home interface and software are ready to communicate.

   (2) An "error" flip-flop which tells the home software that the
       foreign interface has been not ready.

   (3) NOP messages which are used to purge the communication "pipe"
       after the ready line has "flapped" down and back up.

4. ADVICE ON DELAYS TO LIMIT BANDWIDTH

It is advisable to include adjustable delays whose function is to limit
the maximum bandwidth of transfers, as discussed in Report 1822. Only
when the details (such as cable characteristics, memory speed, and
acceptable memory utilization) of a specific application guarantee that
an unregulated transfer rate will be acceptable can these delays be
omitted. Two delays are involved, one in the sender circuit and one in
the receiver circuit. The sender delays up to 10 microseconds
(adjustable) from when the foreign interface drops Ready-For-Next-Bit,
before again turning on There's-Your-Bit. (This is the sum of delays C
and D in Report 1822 Fig. B-1.) The receiver delays up to 10
microseconds (adjustable) from when the foreign interface asserts
There's-Your-Bit, before again turning on Ready-For-Next-Bit. (This is
the sum of delays A and B in Report 1822 Fig. B-2.) When delivered,
interfaces should have these delays set at approximately the maximum
delay. The timing is shown below.

```
                            _____          _____
   sender's TYB  _____!        !_____!        !___


                        _____          _____
    foreign RFNB  ___!        !_____!        !_____
                            !<--delay-->!


                        _____          _____
     foreign TYB  _____!        !_____!        !___


                        _____          _____
  receiver's RFNB  ___!        !_____!        !_____
                        !<--delay-->!
```

5. INTER-OPERABILITY WITH 1822 INTERFACES

Protocol specifications have been chosen which are compatible with
Report 1822. Actually, the protocol areas discussed above are further
clarification of Report 1822, rather than any change from it. The
electrical specifications differ only slightly from the 1822 interface.
The local host levels chosen are 1822 compatible. The potential
difficulties in using a JANUS interface cabled to an 1822 interface
arise with the distant host interface.

The distant host cable for a JANUS interface is 100 ohms nominal
impedance, compared to 120 ohms for the 1822 interface. This difference
is small enough that most applications will work with either cable, or
even with some 100 ohm cable and some 120 ohm cable.

The 1822 distant host interface does not provide as much electrical
isolation as the standard JANUS distant host interface. Thus, in cases
of severe common mode noise or ground potential difference, two JANUS
interfaces might operate correctly, but an 1822 interface might
misbehave or burn out.

The JANUS distant host driver yields 2 to 6 volts output, and its
receiver requires 0.2 volts input; the 1822 distant host driver yields
1.0 volt output, and its receiver requires 0.1 volt input. Unless there
is a significant signal loss in the cable, the 1822 driver will drive a
JANUS receiver acceptably. On the other hand, the maximum input to an
1822 receiver is 4.0 volts. Thus a JANUS driver might overdrive an 1822
receiver. The simplest fix for this is to put a (balanced) voltage
divider at the 1822 receiver, or at the JANUS driver. The divider
should cut down the maximum voltage from 6 volts to 4 volts, or a
reduction of 1/3.

The above differences are relatively minor, so in most applications an
interconnected 1822 interface and a JANUS interface should operate
correctly. Attention must be paid to the electrical isolation
susceptibility of the 1822, and to its maximum input voltage.

6. MILITARY COMPATIBILITY

The EIA specification RS-422 chosen as a base for the JANUS interface
distant host electrical characteristics is compatible with military
specification MIL-188-114.

The common mode voltage tolerance of the JANUS interface provides
significant protection against widely varying ground potentials in field
equipment separated by distances of thousands of feet.

7. REFERENCES

"Specifications for the Interconnection of a Host and an IMP," BBN
Report 1822, revised January 1976; BBN Inc., 50 Moulton St., Cambridge,
Ma. 02138.

"Electrical Characteristics of Balanced Voltage Digital Interface
Circuits, EIA standard RS-422," April 1975; Engineering Dept.,
Electronic Industries Assn., 2001 Eye St., N.W., Washington, D.C.,
20006.

REA bulletin 345-67, Rural Electrification Admin., U.S. Dept. of
Agriculture. Contains specification for PE-39 cable.