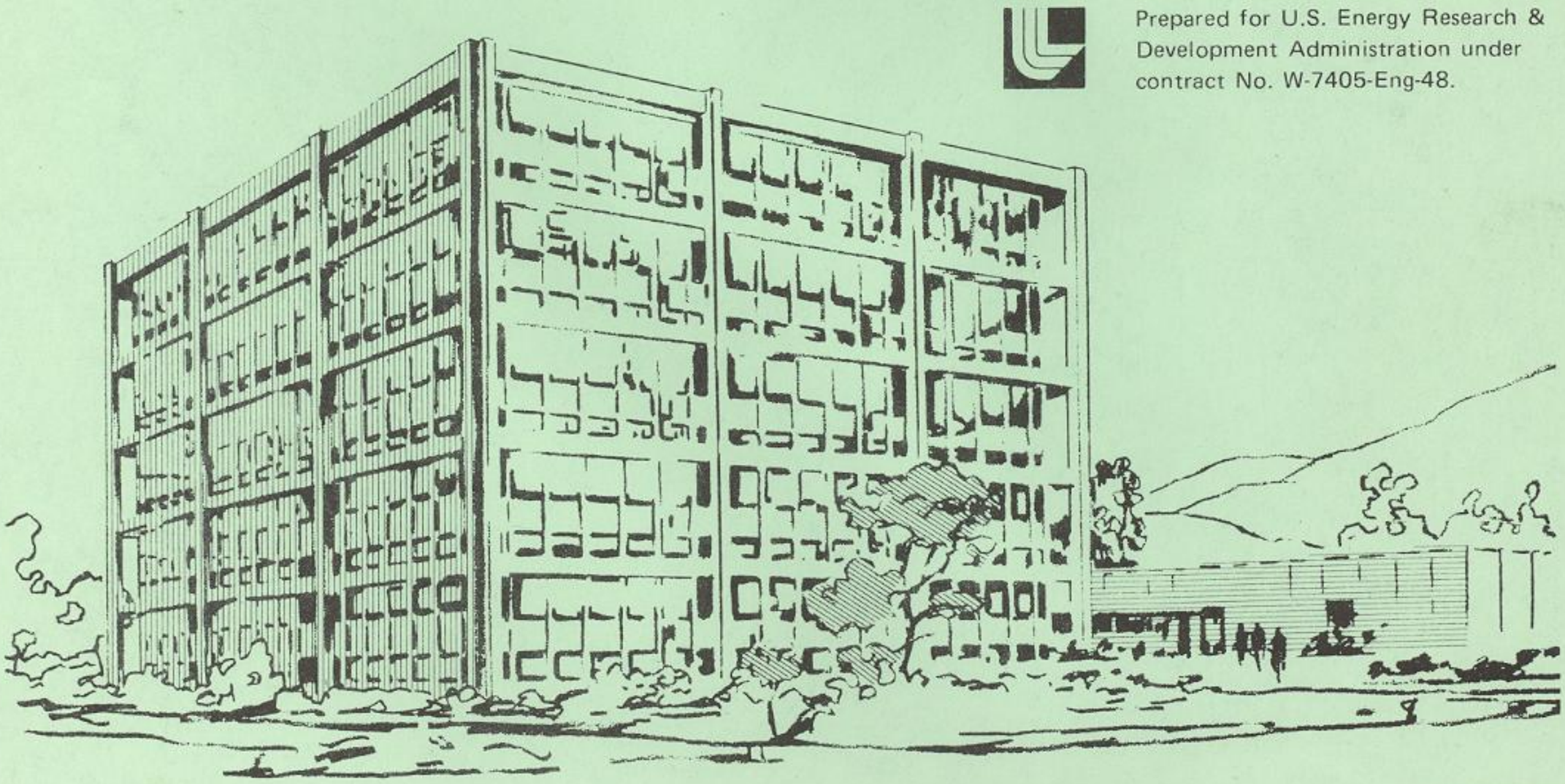
UCID - 30118
COMPUTER
DOCUMENTATION

Lawrence Livermore Laboratory

TMDS MANUAL

John C. Fletcher

February 9, 1976



Prepared for U.S. Energy Research & Development Administration under contract No. W-7405-Eng-48.

CONTENTS

TMDS MANUAL

ABSTRACT

The Television Monitor Display System (TMDS) is an Octopus subnetwork that supports up to 512 television monitor display devices. These devices enable the user to display both text and graphic pictures. This manual explains how the user interacts with TMDS, describes the format of display information, and also covers various aspects of TMDS operation of interest to the system programmer.

1. INTRODUCTION

TMDS (Television Monitor Display System) is a subnetwork of Octopus controlled by two DEC PDP-11/45 concentrator computers. Depending on the context, the acronym TMDS may refer to the system software executing in the PDP-11/45's or to the entire complex of subnetwork hardware shown in Fig. 1. TMDS supports a number of television monitor output display devices. The subnetwork can ultimately expand to 512 monitors, but initially there will be considerably fewer. The subnetwork has no interactive input facilities of its own; it operates in the following manner: A user program executing on a worker computer (almost always being controlled from an interactive terminal on another Octopus subnetwork) sends to TMDS a sequence of messages that establish a connection between the program and a monitor, convey display information, and finally terminate the connection. The general procedure is as follows:

A user gets control of a monitor by sending a request message to TMDS from his program (see Section 4). Then:

(1) an id picture is displayed (Section 2, Fig. 2), and

(2) if necessary, the user confirms that he has seen the id picture.

The user's program may now send program pictures to the monitor in the format described in Section 3, and may also request that the monitor display a link picture (described in Section 2). Link pictures are used primarily to convey status information about the Octopus network. Upon completion, the user's program should request that the monitor be released.

The TMDS discussed here is a new system, not to be confused with an older system of 128 monitors controlled by a DEC PDP-10; the older system is to be phased out. Although the two systems may appear quite similar to the ultimate user, many differences are visible to the programmer at both the user and the system level.

The following discussion covers various aspects of TMDS operation, beginning with those aspects of direct interest to the user at a TMDS monitor and proceeding to matters of interest only to the system programmer. The five remaining sections of the discussion cover in turn (2) the general appearance of the system to the user, (3) the format of display information, (4) the format for user communication with TMDS, (5) the format for system communication with TMDS, and (6) concentrator operation.

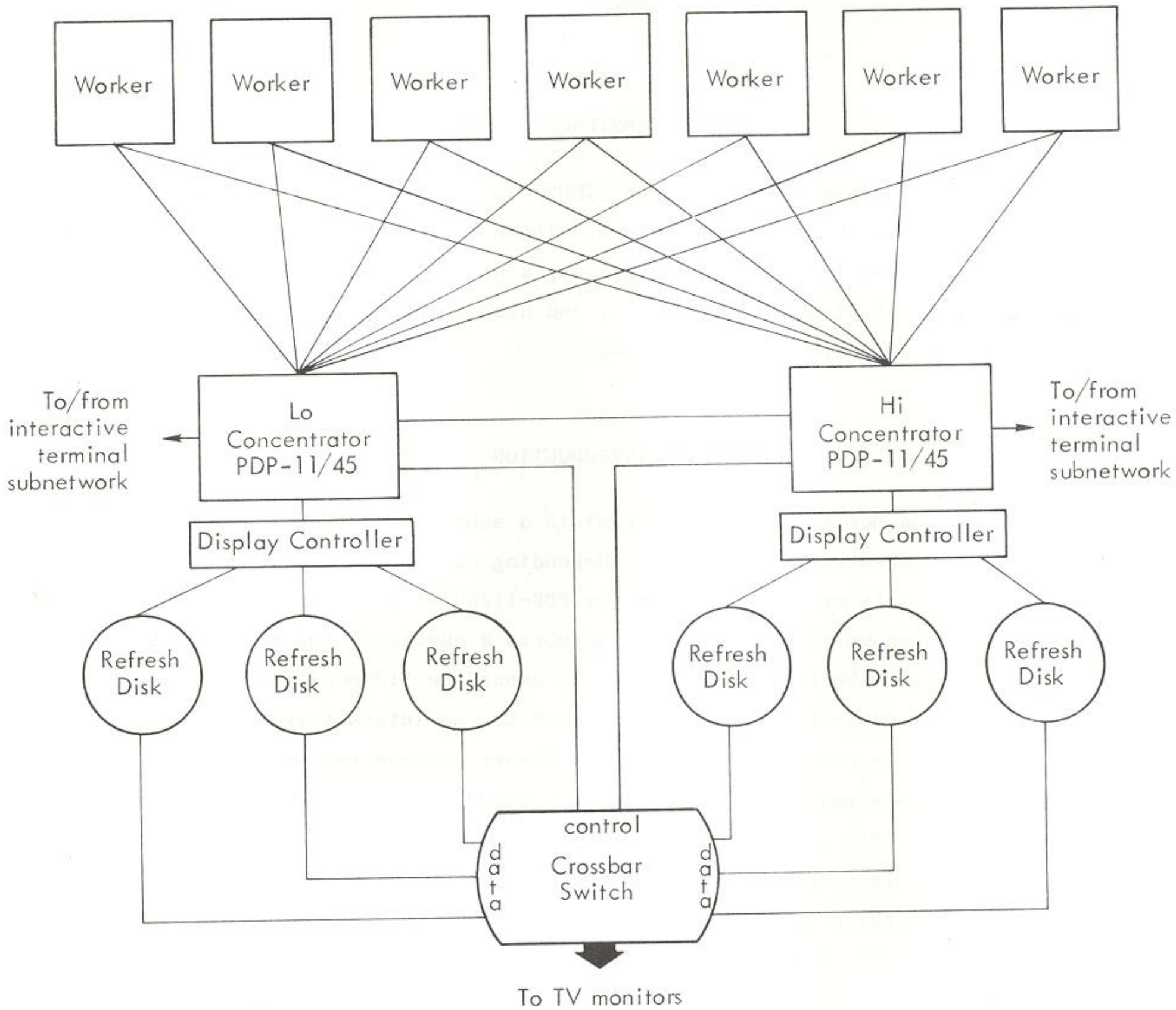


Fig. 1. TMDS subnetwork.

2. USER INTERFACE

Monitors

Fanning out from TMDS are up to 512 cables, each identified by a unique three-digit octal number. Information is sent out along a cable at over 7-1/2 million bits per second. The information describes a sequence of television pictures each of which consists of a square raster of 256K points (where K = 1024), 512 points on a side; a point being either bright or dark. A new picture is sent every 1/30 second; at this rate the displayed pictures have only a minimal flicker. Successive pictures sent on a cable are usually the same; the system will not support changes in pictures at rates approaching 30 per second. The pictures sent out on each of the 512 cables can be independently selected.

The typical cable terminates in a single television monitor, which should bear a label showing the identifying number of the cable and which displays the pictures sent over that cable. In some cases two or more monitors share a cable and therefore always display a common picture. The picture is composed of only two kinds of points, bright and dark, and shows no color or gray-tone. Certain monitors, however, are attached to more than one cable each and can display more complex pictures. A color monitor is attached to three cables, with each cable carrying the raster corresponding to one of the primary colors. A gray-tone monitor is attached to n number of cables and uses the rasters on these cables in such a way as to compose a single picture with 2^n levels of gray. Color and gray-tone features also can be combined into a single monitor. Monitors attached to several cables should be labelled with the numbers of all those cables, and the labels should indicate the significance of each cable to the monitor. The user of such a monitor is treated by TMDS as a user of several monitors, since TMDS recognizes only cables and is not aware of whether or not they lead to the same or different monitors.

A monitor (i.e., cable) is recognized by TMDS as being in one of two states: busy or free. A busy monitor is one that has been assigned to a single user and is controlled by that user's programs, while a free monitor is not assigned to any particular user. For each busy monitor, TMDS remembers a single picture, the program picture, which either is the id picture that is generated by TMDS when the monitor is first assigned to the user or is a picture that has been sent to TMDS by the user's program. However, the picture that appears on a busy monitor is not always the program picture; it may instead be one of the nine link pictures that are primarily used to display status information about the Octopus network. A free monitor always shows one of the link pictures. When TMDS is initialized, all the monitors except monitor 000 are free. (Monitor 000 is reserved for system maintenance and debugging.)

Channels

The raster defining each (program or link) picture remembered by TMDS is stored on a channel of a video refresh disk. There is provision for up to 256 channels, but only 96 are currently implemented. Each channel is identified by a unique three-digit octal

number less than 400. The first half of these channels, identified by octal numbers less than 200, are controlled by one of the two TMDS concentrators (the Lo concentrator), while the latter half, identified by octal numbers 200 or greater, are controlled by the other concentrator (the Hi concentrator). The currently implemented channels are numbered 000 through 057 and 200 through 257; thus each concentrator controls half of the implemented channels. A single refresh disk has 16 channels; so each concentrator can control up to eight disks, with only three being currently implemented. The channels on a disk are consecutively numbered beginning at a multiple of 20_8. Each channel stores only one picture at a time.

An implemented channel is recognized by TMDS as being in one of three states: busy, link, or free. A busy channel holds the program picture for a busy monitor; so each busy monitor is associated with exactly one busy channel, and vice-versa. A link channel holds a picture that is used only as a link picture; however, as is explained below, not all link pictures are stored on link channels. The free channels (those that are neither busy nor link) constitute a pool from which a new busy channel is allocated to be attached (by means of a crossbar switch) to a newly busy monitor and to which a busy channel is returned when the attached monitor becomes free. When TMDS is initialized, the necessary number of channels are set aside as link channels, and the remaining channels are placed into the pool of free channels.

Id Picture

A free monitor becomes busy and is assigned to a user as a result of a request message sent to TMDS by that user's program. (The format of this and other request messages is described in Section 4.) When the request is honored, a busy channel is allocated to hold the program picture for the monitor, and the id picture is recorded onto it. An example of an id picture is shown in Fig. 2. The information in it is as follows:

In the upper left corner appears "Channel #" followed by the three-digit octal number of the channel. The user viewing the picture may be interested in taking note of this number, but it is not necessary to do so.

In the upper right corner appears "Monitor #" followed by the three-digit octal number of the monitor. This should of course be the same as the number with which the monitor is labelled and which was included in the request message asking for the monitor. There is no permanent or predictable relationship between the monitor number and the channel number. Whenever a given free monitor becomes busy, a channel is assigned without regard to previous assignments.

Just above the center of the picture appears the six-digit decimal user number of the user whose program requested the monitor.

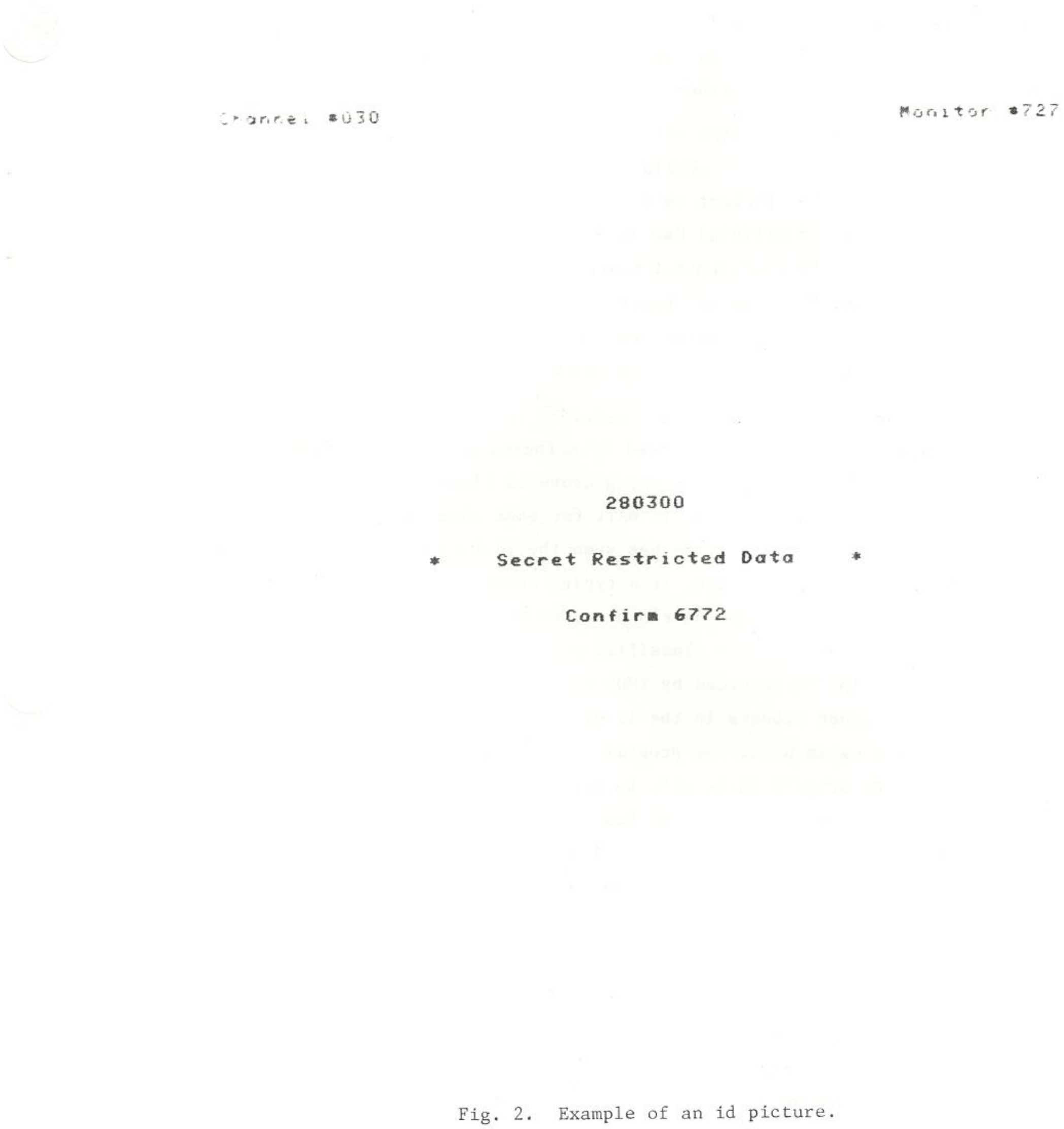


Fig. 2. Example of an id picture.

Below the user number appears a declaration of the protection level that will be associated with the monitor while it is busy; this level is determined by the program requesting the monitor. The declarations corresponding to each of the eight levels are:

```
n: declaration entirely blank,
u: "*          Unclassified          *",
p: "*  Protect as Restricted Data    *",
a: "* Official Use Only - P.A.R.D.   *",
c: "* Confidential Restricted Data   *",
s: "*    Secret Restricted Data      *",
t: "*  Top Secret Restricted Data    *",
k: "*  Octopus System Secret R.D.    *".
```

If and only if the level is classified (i.e., is c, s, t, or k), then below the level declaration appears "Confirm " followed by a four-digit octal confirm number generated at random by TMDS. The rest of the picture is blank.

A properly written user program should wait for some indication from the user (sent through his interactive terminal) that he has seen the id picture before it begins outputting program pictures. Otherwise, if a typing error or other mishap has caused the wrong monitor to be selected, the user's pictures may appear where they can be seen by persons unknown to the user. If a classified protection level is involved, the desired manner of operation is enforced by TMDS through the use of the random confirm number. If a confirm number appears in the id picture, TMDS will not accept a program picture from the user program until the program first sends it a message containing the confirm number. For the program to be able to supply the proper number, that number must be conveyed to it by the user (through his interactive terminal); in so doing, the user confirms that he can see the id picture. A user program could try to "guess" the confirm number, but TMDS allows it at most three bad guesses. When TMDS receives the correct confirm number, it replaces "Confirm " and the number with "Confirmed!"

Using a Busy Monitor and Channel

After a user program has successfully requested and, if necessary, confirmed a monitor, it (or any other program associated with the same user) may send program pictures to that monitor. (The language used to describe the pictures is explained in Section 3.) The program may also request that the monitor display one of the link pictures or that it return to displaying the program picture. When the display activity is complete, the program should request that the monitor be released (to become free, together with the attached channel). What the user must type at his interactive terminal to cause his program to carry out these activities depends upon the nature of the user program. Specific user programs are not described here; each is described in a publication of its own.

TMDS demands that the user of a busy monitor and channel interact with them at some minimum frequency. If the interval between successive interactions is too long (where

an interaction is any message in regard to the channel from the user program to TMDS), TMDS preemptorily breaks the association with the user and frees the monitor and the channel. The time-out intervals are (within a tolerance of - 15 seconds):

Level	Time-out interval (minutes)
Not classified (n, u, p, or a)	64
Classified (c, s, t, or k) and confirmed	8
Classified and unconfirmed	2

If the level is classified and unconfirmed, a 30-second penalty is imposed for each confirm message containing the wrong number; thus issuing as many as three incorrect confirmations without losing the monitor is possible only if they are issued within 30 seconds or less.

When a busy channel becomes free, TMDS erases the program picture and records "Channel #" followed by the three-digit octal number of the channel in the upper left corner of the picture (as in the first item of the id picture). Sometimes a brief glimpse of this free channel picture can be seen just before a link picture appears on the newly free monitor.

Link Selection

While the program picture is being displayed on a busy monitor, TMDS remembers which of the nine link pictures was most recently displayed on that monitor. When the monitor becomes free, that same most recently displayed link picture reappears, unless the user program specifically selects a different one. In fact, a user program may request a change in the link picture that appears on any free monitor (as well as on the busy monitor associated with the program). This enables a user at an interactive terminal that is logged in to a worker computer to easily select the link picture on a free monitor that he is looking at without having to first request that the monitor be assigned to him.

A method has also been provided for a user at an interactive terminal that is not logged in to any worker computer to select the link picture on any free monitor. All he need do is log in to the "V" (for video) computer by typing "v" (which is echoed as "idv ") followed by the three-digit octal number of the monitor and then by a single-letter mnemonic identifying one of the nine link pictures; the message is ended by a linefeed or other terminal character. For example, the message might be

```
idv 727 b
```

which selects the picture identified by the mnemonic "b" to appear on monitor 727. (The various link pictures and their mnemonics are described below.) The mnemonic may be omitted, in which case the link that has been designated as the standard link is selected; the standard link is also selected for all monitors (except monitor 000) when TMDS is initialized. The standard link is currently the rotating picture described below.

The response to the V computer login is one of the following four messages, followed by carriage return and two linefeeds, after which the terminal is again logged out:

Message	Meaning
"Done."	The change in the link picture was effected, as should be reflected on the monitor. If any other reply is received, the requested selection could not be made for the reason indicated by the reply.
"Inappropriate level."	The protection level associated with the selected picture is too high; only level n link pictures may be selected by a V computer login. (Further details on levels are discussed in Section 4.)
"Meaning undefined."	The message had the wrong format or included an undefined mnemonic.
"Monitor unavailable."	The monitor named in the message is not free.

In addition, the message "@Bye" might be received. This means that the typed message could not reach the TMDS concentrator because of a failure in the network.

Link Pictures

Each of the nine link pictures is identified by an integer from zero through eight as well as by a single-letter mnemonic; also, each has an associated protection level. A link picture may be displayed on any number of monitors simultaneously (in contrast with a program picture which is displayed on at most one monitor). The link pictures are described below and summarized in Table 1.

Message Picture

Link picture 0, the message picture (mnemonic m), level n, includes broadcast messages generated by computer operators and other information that should aid the user in determining the status of the Octopus network and its components; it therefore is classed as a status picture. The information in status pictures is assembled by TMDS from information sent to it at regular intervals by the various computers of the network. Each status picture is stored on a link channel. An example of a message picture is shown in Fig. 3. Horizontal and vertical lines enclose the picture and subdivide it into many rectangular fields. All the fields enclosed between the same pair of adjacent horizontal lines (forming an area that extends the full width of the picture) constitute a band.

```
          →    D/S    09/02   08:00          12X                    A   09/02/75
A-machine all right for timesharing.                                 ↑   11:59:58

          B    D/S    09/02   01:23          120                    B   09/02/75
B-machine beautiful for timesharing.                                 ↑   12:00:01
 Disks are full.  Please destroy all unneeded files.  Thanks.

          R    D/S    09/01   20:00          41M                    R   09/02/75
R-machine right on  for timesharing.                                 ↑   12:00:01
Tapes to vault promptly at 15:00.

          S    D/S    09/02   09:36          41K                    S   09/02/75
S-machine superior  for timesharing.                                 ↑   11:57:44

          T    D/S    08/31   00:18          41M                    T   08/31/57
T-machine terrible  for timesharing.                                 ↓   04:32:10
 Down until 9/04 with faulty grammus.

          U    D/S    08/29   12:34          42A                    U   09/02/75
U-machine unequaled for timesharing.                                 ↑   12:00:02

          P    D/S    09/02   07:56          (HYDRA7)    CPU 0      P   09/02/75
 For assist call: "Help!"                                            ↑   12:00:00
  or control center X3465

PS  Up and available                                          TMDS
DC  Up and busy                                          Lo ↑  31 Ch
FT  Up and moving                                        Hi *  17 Ch

 Solvall version #69 restored on all machines, 8/30.          Terms
                                                              0000 ↑
                                                              0200 ↑
Power outage scheduled for week of 9/14.                      0400 ↑
                                                              0600 ↑
                                                              1000 ↑
                                                              1600 ↑
```

Fig. 3. Example of a message picture (Link Picture 0).

The top portion of the screen (above the upper horizontal double line) contains a number of bands, each of which consists of three fields that contain information relating to a single worker computer; the worker is identified by a large letter displayed in the middle field. The large left-hand field contains up to three one-line messages relating to the worker. The topmost message is supplied by the worker when it deadstarts, while the other two are generated by computer operators as the need arises. The right-hand field shows the date (month, date, year) and time (hour, minute, second) at which status information was last received from the worker by TMDS. The workers and other computers in the network are expected to send status information to TMDS at five-second intervals, which is the same as the interval at which the status pictures are updated by TMDS. Therefore, unless the worker is down, the time displayed should increment by five seconds every five seconds. If the times displayed for any two workers that are up differ by more than five seconds, then the clocks on the two workers are out of synchronism; TMDS displays a time sent to it by the worker, not a time read from a clock of its own. Below the letter in the middle field that identifies the worker is an arrow pointing up or down, depending on whether TMDS judges the worker to be up or down. A computer is judged up so long as it sends status information at least once every ten seconds (half the expected rate); otherwise it is judged down. An up arrow is normally associated with a changing time in the right-hand field, and a down arrow is associated with a fixed time (the time at which the worker went down).

Table 1. Link Picture Summary

Picture No.	Name and Mnemonic	Protection Level	Description
0	Message (m)	n	Includes messages concerning status of the Octopus network.
1	Network (n)	n	Displays a dynamic diagram of the Octopus network.
2	-Unimplemented-		Reserved for additional status picture.
3	-Unimplemented-		Reserved for additional status picture.
4	Rotating (r)	n	Displays status pictures in rotation.
5	-Unimplemented-		Reserved for future use.
6	Show (s)	n if blank; or program picture level	Displays a particular user's program picture.
7	Debug (d)	k	Used for TMDS hardware and software debugging.
8	Blank (b)	n	Always blank (used to rest a monitor without turning it off).

The band just below the middle of the picture (between the two double horizontal lines) consists of two fields. The large left-hand field contains three messages relating to the Elephant central storage subnetwork. Each message is labelled at the left to indicate the aspect of Elephant to which it refers; the labels are (from top to bottom) "PS" for photostore, "DC" for Data Cell, and "FT" for file transport. The right-hand field is labelled "TMDS" at the top to indicate that it contains information about TMDS itself. This information is displayed in two lines; each line refers to one of the two concentrators and is labelled "Lo" or "Hi" at the left to indicate which concentrator. Following one of the labels is an asterisk (*); the concentrator so marked is currently the master TMDS concentrator. The master concentrator is the one that maintains the status pictures and controls the crossbar switch that connects channels to monitors. (Further details about the role of the master concentrator are given in Section 6.) Following the label of the other concentrator, the slave concentrator, is an arrow indicating whether that concentrator is up or down; this arrow is updated according to the same algorithm that governs the arrows associated with the worker computers. An up/down indication is unnecessary for the master concentrator, since it must be up in order to update the status picture. The master may be inferred to be down if the regular (five-second) updating of the status pictures ceases; to make the updating noticeable, the label "TMDS" blinks at the time of the update. Following the asterisk or arrow associated with each TMDS concentrator is a two-digit decimal number and the letters " Ch" (meaning channels). The number indicates how many free channels are available on the concentrator. If both channel counts are zero, the system is saturated. (Also, of course, any channels shown for the slave concentrator are unusable if it is down.)

The bottom band (below the lower horizontal double line) consists of two fields. The large left-hand field contains up to eight one-line messages. These are generated by computer operators as the need arises and should relate to the network as a whole; messages relating to a specific worker should appear in the band associated with that worker. The right-hand field is labelled "Terms" at the top to indicate that it contains information about the interactive terminal concentrators. Each line in the field is labelled at the left with a four-digit octal number identifying a concentrator. Following the label is an arrow indicating whether that concentrator is up or down, just as with the workers and the slave TMDS concentrator.

Network Picture

Link picture 1, the network picture (mnemonic n), level n, is a dynamic diagram of the Octopus network. An example of it is shown in Fig. 4. The (worker and concentrator) computers are displayed as squares appropriately labelled in their interiors. The intercomputer connections are shown as lines joining the squares. The network picture is more than a static rendering of network structure; it is a status picture that shows which intercomputer connections are currently functioning. The line representing a

defective connection shows a gap at one or (usually) both ends. More precisely, a gap at one end of a line means that the computer at that end of the line cannot successfully output data over the interconnection; i.e., transmission away from the gap along the line is down. Transmission toward the gap is up unless (as is usually the case) a gap also appears at the other end of the line. Thus each end of a line represents an output interface for the adjacent computer and indicates whether that interface is up or down. Each computer sends the status of all its output interfaces to TMDS. Its opinion regarding the interface is based on whether or not the most recent output attempted on that interface succeeded; an interface is deemed up or down only by being used. If TMDS judges a computer to be down (because no status information has been received for ten seconds), then it also judges all that computer's output interfaces to be down: a square entirely surrounded by gaps represents a down computer, e.g., the T-machine in Fig. 4.

The lower right corner of the picture contains a two or three-digit decimal number followed by " interfaces down". This number (which blinks at every update of the picture) represents a count of the gaps in the schematic diagram and should aid the user in making certain that none of them are overlooked. In the lower left corner of the picture appears the message "TMDS up " nn " days " nn " hours", where the two-digit decimal numbers nn indicate how much time has elapsed since the last TMDS deadstart (rounded down to the nearest hour).

Link pictures 2 and 3 are currently unimplemented (appearing blank) and are reserved for future use as additional status pictures.

Rotating Picture

Link picture 4, the rotating picture (mnemonic r), level n, is always the same as one of the status pictures. Every 12-1/2 seconds it changes to a new status picture, proceeding through all the implemented status pictures in rotation. By selecting this link, the user is exposed to all the available status information. The rotating link is the standard link.

Link picture 5 is currently unimplemented (appearing blank), and is reserved for future use.

Show Picture

Link picture 6, the show picture (mnemonic s), either is blank and of level n or is the same as some user's program picture and has the level of that picture. By means of a message to TMDS from his program, any user can request that his program picture be made the show picture (see Section 4). If the request is granted, then (by selecting the show link) other users interested in the picture may view it from other monitors, which may be more convenient to them. The user showing his picture on the show link should be aware that he cannot prevent users unknown to him from seeing the picture. Also, he should release the link as soon as possible, so that other users can show their pictures.

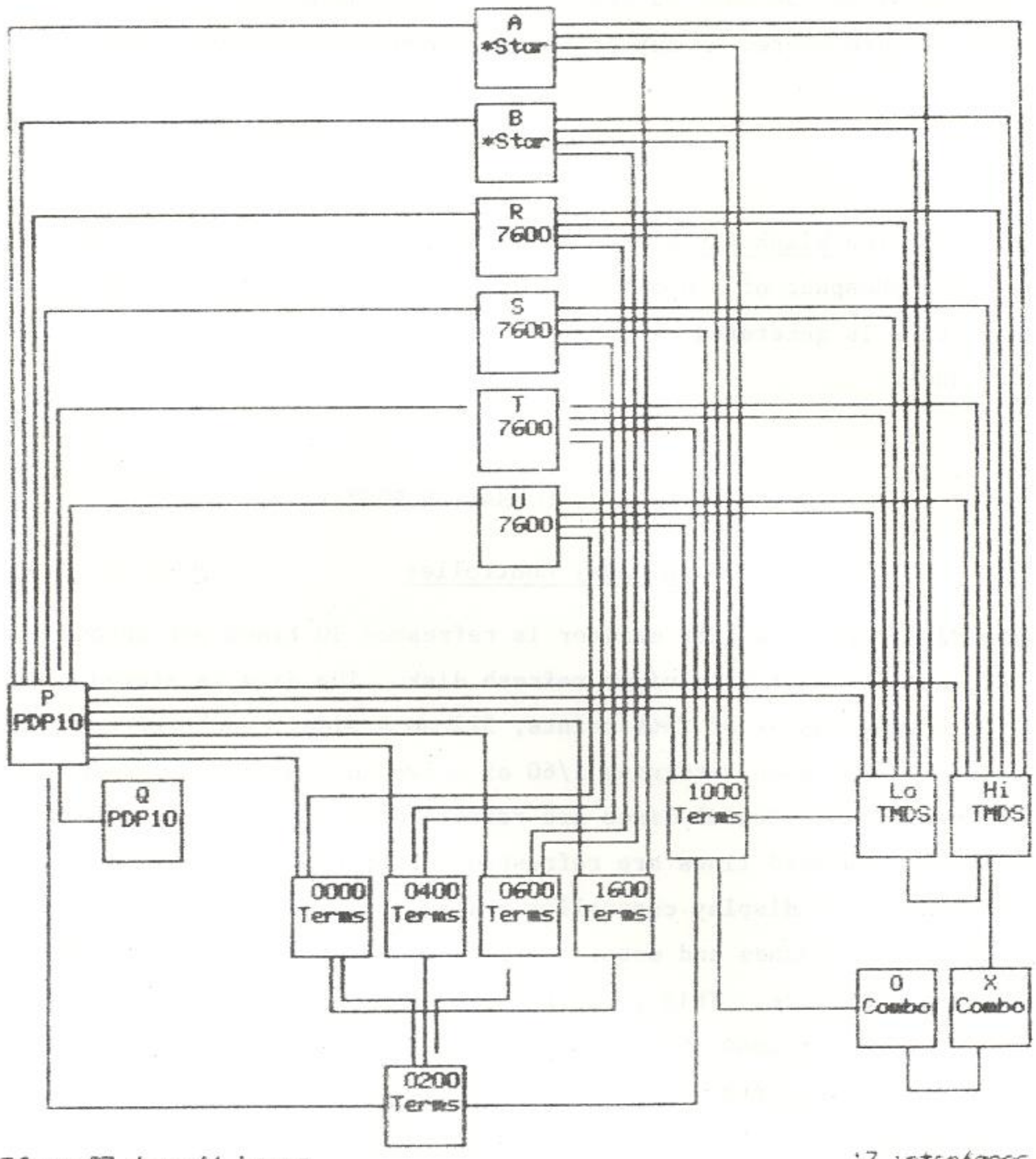


Fig. 4. Example of a network picture (Link Picture 1).

Debug Picture

Link picture 7, the debug picture (mnemonic d), level k, is used for TMDS hardware and software debugging and because of its level is available only to authorized users. It can carry the picture stored on any of the channels. Monitor 000 always displays this picture.

Blank Picture

Link picture 8, the blank picture (mnemonic b), level n, is always blank. It can be used to give the phosphor of a monitor a rest without adjusting the monitor or turning it off. This picture is generated directly by the crossbar switch and does not use a refresh disk channel.

3. DISPLAY INFORMATION FORMAT

Display Controller

Data being displayed on a TMDS monitor is refreshed 30 times per second from a copy of the data held on a channel of a video refresh disk. The data is stored on the disk in the form of a square raster of 256K points, 512 on a side. Each refresh cycle consists of two successive fields, each requiring 1/60 of a second; during one field (the odd field) all odd-numbered horizontal lines are refreshed, and during the other field (the even field) all even-numbered lines are refreshed. TMDS places picture data onto the refresh disk by means of a display controller which interprets the stream of bits sent to it as a sequence of commands and data. Refresh of a picture is suspended while the controller alters the picture. This gives the effect of a 1/30 sec. blinking in the vicinity of the altered portions of the picture. This section describes the format of the display information interpreted by the controller; in the case of a program picture this information, supplied by the user program, is passed to the controller by TMDS unaltered and unexamined.

The format for display information is oriented around the chomp. A chomp consists of two consecutive eight-bit bytes. In a worker computer, the chomps are packed tightly without regard to word boundaries. Each chomp is regarded as a command until the command block transfer is encountered. This command includes a byte count; the chomps immediately following this command are regarded as containing bytes of display data equal in number to the byte count. (If the byte count is odd, the last byte of the last data chomp is ignored.) The chomps following the data are again interpreted as commands until another block transfer command is encountered.

Command Format

The bits of each 16-bit command are numbered from 15 to 0, left to right. The first six bits (15-10) are the op code defining the type of command. TMDS recognizes eight

user op codes and three system op codes. All other op codes are illegal, and system op codes are illegal in program pictures. Commands having illegal op codes are treated as no-operations, but a record is made by the controller that an illegal op code has been processed.

The following command descriptions include a suggested three-character mnemonic for each op code, additional mnemonics for bit fields within some of the commands, and a suggested format suitable for an assembly language.

User Commands

The eight commands described below are available to the user and the system. They are:

- Load Control Register - LCR (select various display options)
- Load Font 0 Size - LF0, and Load Font 1 Size - LF1 (set the size of the indicated font)
- Load X-coordinate -LDX, and Load Y-coordinate -LDY (set raster position for subsequent data)
- Block Transfer - BXF (signal the beginning of data bytes)
- Load Data - LDD (define a single data byte)
- Idle - IDL (no operation)

Load Control Register (LCR)

Format:

15 10	9	8	7	6	5 4	3	2 1	0
Op Code: LCR (41_8)	E erase screen	W word data	G graphic, not text	N record nega-tive	0(1) font 0 1(2) font 1 2(3) double-size font	I display in-verted	A(1) additive R(2) replace L(3) line replace	V step vertical

Description: LCR selects options that prevail until the next LCR command. In assembly format, the LCR mnemonic is followed by a string of single-character mnemonics, each representing a selected option. A selected option causes a single bit in the command to be set to 1 or causes a pair of bits to take on a specified non-zero value.

Bits 15 through 10 are the op code: 41_8.

Bit 9, if set (E), indicates that the full raster should be erased, provided that bits 8 and 7 are clear. If bits 8 or 7 are set when bit 9 is set, all three bits are ignored, and no change is made in the options that they control. If bit 9 is clear, bits 8 and 7 are interpreted as explained next.

Bit 8, if set (W), indicates that the two bytes within each data (not command) chomp are to be processed in swapped order; otherwise they are processed in normal order. Swapped order is rarely used; the option exists because of a distinction between chomps and computer words on PDP-11's.

Bit 7, if set (G), indicates that data is to be interpreted as graphic raster bits; otherwise data is interpreted as text. The bits of a graphic raster byte are recorded into eight successive points of a raster line. The bits of a text byte are used to select one of 256 characters from a predefined font table; the raster representation of the selected character is placed into the recorded raster.

Bit 6, if set (N), indicates that data bits should be recorded as a negative image; that is, zeros, rather than ones, should produce bright points, and ones, rather than zeros, should produce dark points. Similarly, if erase (E) is indicated (by bit 9), the entire raster becomes bright, rather than dark. If bit 6 is clear, recording is positive.

Bits 5 and 4 select one of four text modes, which are relevant only if data is interpreted as text (bit 7 clear). If the two bits are 00 (no mnemonic), standard 256-character mode is indicated in which each text byte selects one of 256 predefined characters as stated above. If the two bits are 01 (mnemonic 0), then the high-order bit of each text byte is ignored and treated as though it were zero. Thus only the first 128 characters of the full font table are accessible; these 128 characters constitute font 0. If the two bits are 10 (mnemonic 1), then the high-order bit of each text byte is ignored and treated as though it were one. Thus only the last 128 characters of the full font table are accessible; these 128 characters constitute font 1. If the predefined font table consists of a single set of 256 different characters, the latter two modes are probably not of much use. However, if it actually consists of two fonts of the same 128 characters (perhaps differing in size), then the latter two modes are quite valuable, while the 256-character mode permits the two fonts to be freely intermixed. In the three modes described thus far, the maximum size of a character is 8 raster points wide and 16 points high. If bits 5 and 4 are 11 (mnemonic 2), then a double-size mode is selected in which there are only 128 characters altogether, but each character can be up to 16 points wide by 16 points high. The high-order bit of each byte is ignored in selecting the character. If the predefined font is suitable for this mode, it is probably unsuitable for the former three modes, and conversely.

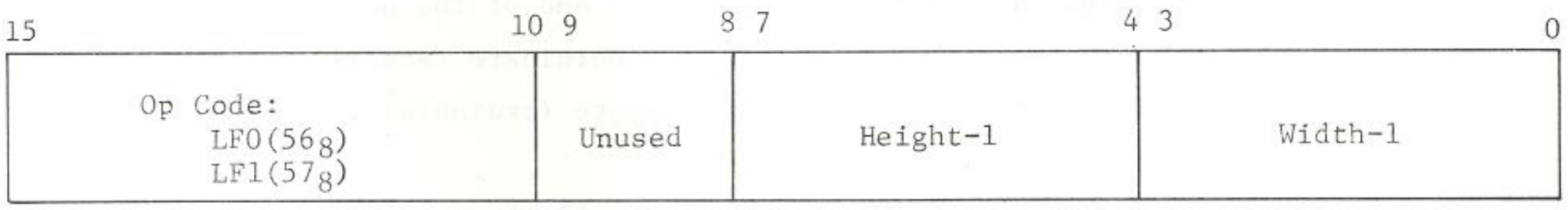
Bit 3, if set (I), indicates that the recorded raster is to be displayed as a negative or inverted image; otherwise it is displayed uninverted. The effect of this bit should not be confused with that of bit 6, which only affects how subsequent data is to be recorded onto the video disk. Bit 3 does not change the recorded raster, nor does it affect the recording of subsequent data; it does cause all recorded points to be displayed inverted, with dark points appearing bright, and conversely. Therefore bit 3 of only the most recent LCR command determines whether the recorded image is to be inverted as it is transmitted to the monitor.

Bits 2 and 1 select among three recording modes. If the two bits are 00 (no mnemonic), the mode is unchanged and retains its previous value. If the two bits are 01 (A), additive mode is selected. In this mode, only ones are recorded on the refresh disk (as bright or dark points as determined by bit 6); raster points corresponding to zeros in the data are unaffected. If the two bits are 10 (R), replacement mode is selected. In this mode, all bits are recorded on the video disk; thus not only is a text character itself recorded, but also the entire rectangle determined by the font size, making some points bright and others dark. If the two bits are 11 (L), line replacement mode is selected. In this mode, every raster line on which data is recorded is first erased (to dark or bright as determined by bit 6). For example, if a single character is recorded, all preceding and following character positions in the same row of characters become blank.

Bit 0, if set (V), indicates that successive characters of text data are to be placed below, rather than to the right of, preceding characters; otherwise, characters progress in normal left-to-right fashion. This step-vertical mode must not be used in connection with graphic raster data (bit 7 set).

Load Font Size (LF0 and LF1)

Format:



Description: LF0 and LF1 set the size of the indicated font. In assembly format, the LF0 or LF1 mnemonic is followed by the font width and height (in that order) separated by a comma. In 256-character mode, the high-order bit of each text byte determines which font size is used; therefore the two sizes should be set the same if the font table contains one set of 256 characters. In double-size character mode, the high-order bit selects the size (but it is not used in selecting the character). An entry in the font table consists of an 8-by-16 or a 16-by-16 raster; a rectangle from the upper left corner of this raster is determined by the font size, and only bits from this rectangle are recorded when the entry is selected by a text data byte. A font usually has a size with which it is intended to be used, and the unused bits to the right and below in the font entry are normally set to zero. Thus, using a larger size than intended increases the intercharacter spacing; using a smaller size may truncate the character. The size selected by a LF0 or LF1 command prevails until the next such command for the same font. A font size should not be changed between two successive recorded lines.

Bits 15 through 10 are the op code: 56_8 for LF0, 57_8 for LF1.

Bits 9 and 8 are unused.

Bits 7 through 4 define a number one less than the height of the font, which may therefore vary from 1 to 16. However, characters of height one, besides being somewhat foolish, may be rejected by the controller if several of them are closely spaced vertically.

Bits 3 through 0 define a number one less than the width of the font, which may therefore vary from 1 to 16. The high-order bit is ignored unless double-size character mode is used.

Load Coordinate (LDX and LDY)

Format:

15	10	9	8	0
Op Code: LDX (66_8) LDY (67_8)		Unused		Coordinate

Description: LDX and LDY set the raster position to be used as the starting point for subsequent data. In assembly format, the LDX or LDY mnemonic is followed by the coordinate value. The selected point defines the left end of the next raster byte or the upper left corner of the next character. The X-coordinate (abscissa) is numbered from 0 on the left to 511 on the right; the Y-coordinate (ordinate) is numbered from 511 at the top to 0 at the bottom.

Bits 15 through 10 are the op code: 66_8 for LDX, 67_8 for LDY.

Bit 9 is unused.

Bits 8 through 0 define the coordinate.

Block Transfer (BXF)

Format:

15	10	9	0
Op Code: BXF (46_8)		Byte count	

Description: BXF signals the beginning of data bytes and indicates their number. In assembly format, the BXF mnemonic is followed by the byte count; the proper number of succeeding chomps should be assembled as data. Whether the bytes are graphic raster or text is determined by a preceding LCR command. Graphic raster bytes are recorded on a single horizontal line beginning at the current X, Y position. If part of a byte extends beyond column 511, it is truncated. A byte should not begin beyond column 511; therefore the byte count for raster data should never exceed a maximum that, depending on the initial

value of X, varies from 1 to 64. After all the data is recorded, the X-coordinate reverts to the value specified by the most recent LDX command, and the Y-coordinate is decremented by one. Thus a succession of BXF commands effect the recording of successive raster lines beginning at the same X-coordinate.

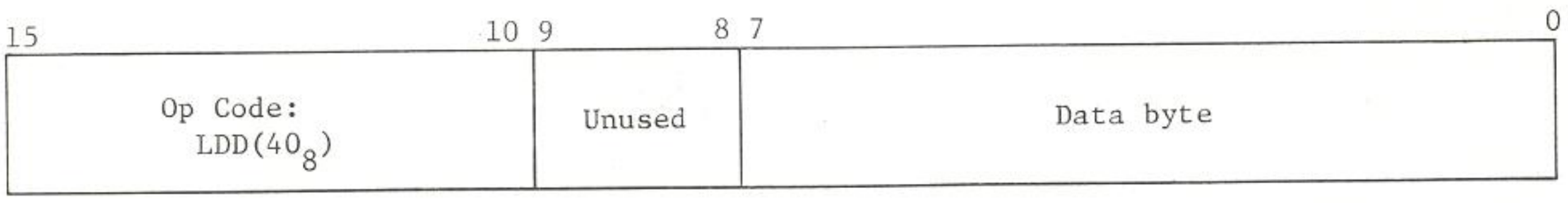
Text bytes select entries from the font table which are recorded on as many lines as are determined by the font size. Successive characters follow to the right with a spacing determined by the font width (or, in step-vertical mode, follow below with a spacing determined by the font height). Characters extending beyond column 511, or below line 0, are truncated. If, as a result of stepping to the right, a character is about to begin in a column beyond 511, the X-coordinate is automatically reset to the value specified by the most recent LDX command and the Y-coordinate is decremented by the height of the last character recorded (decrementing below line 0 should not be allowed to occur); thus several rows of characters beginning at the same X-coordinate may be recorded with one BXF command (in contrast to the situation with graphic raster data, which requires a BXF command for every line). Similar behavior occurs in step-vertical mode if a character is about to begin below line 0. When all text data associated with a BXF command have been recorded, the X-coordinate is reset to the value specified by the last LDX command, and the Y-coordinate is decremented by the height of the last character recorded (or, in step-vertical mode, the X-coordinate is incremented by the width of the last character recorded, while the Y-coordinate is reset). A single BXF command may not record more than 128 characters in a single row; this rule is of significance only if a font width is three or less.

Bits 15 through 10 are the op code: 46_8.

Bits 9 through 0 define the byte count. The command is followed by half this number of data chomps, rounded up to the next integer; the last byte of the last chomp is unused if the count is odd. If the count is zero, the command skips a number of lines equal to the font 0 height, if in text mode, or skips one line, if in raster mode.

Load Data (LDD)

Format:



Description: LDD defines a single data byte. In assembly format, the LDD mnemonic is followed by a representation for the data byte. This command has the same effect as a BXF with a count of one, followed by the data byte.

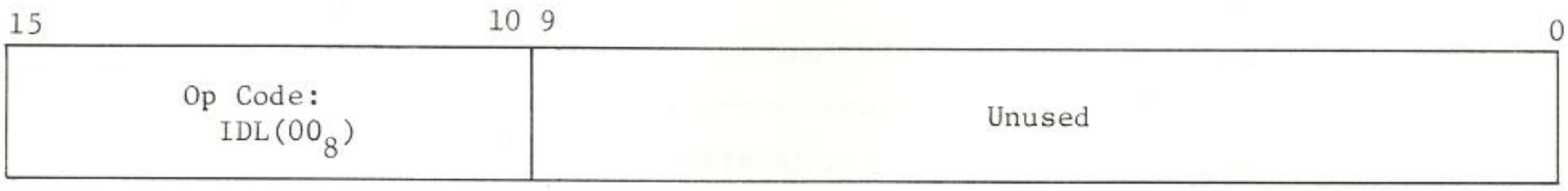
Bits 15 through 10 are the op code: 40_8.

Bits 9 and 8 are unused.

Bits 7 through 0 define a data byte.

Idle (IDL)

Format



Description: IDL is a no-operation.

Bits 15 through 10 are the op code: 00_8.

Bits 9 through 0 are unused.

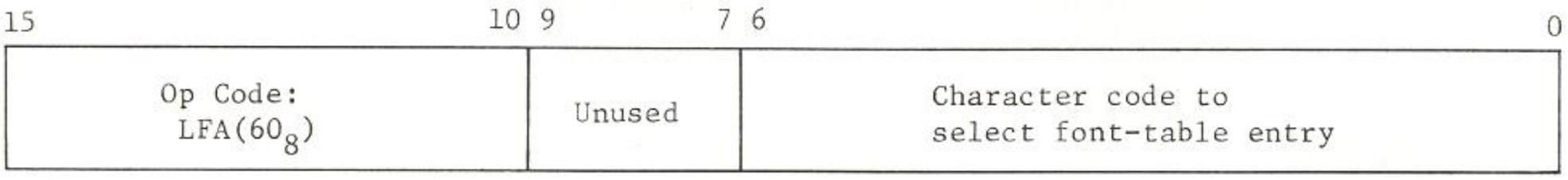
System Commands

The three commands described below are used by TMDS to perform functions prohibited to the user. When a program picture is to be processed, TMDS puts the controller into a special mode that makes these commands illegal. The three system commands are:

- Load Font Address - LFA (load the font table)
- Clear System - CLS (initialize the video disk controller)
- Load Channel Address - LCA (select a disk channel to record data)

Load Font Address (LFA)

Format:



Description: LFA loads the font table. In assembly format, the LFA mnemonic is followed by a character code that defines a character entry within the table. The operation of the first BXF command following an LFA is modified. The count in that command (which should not exceed 128) indicates how many sets of 16 data chomps follow it. Each set of 16 chomps constitutes the raster bits for two font-table entries: The high-order bytes of the 16 chomps are an entry for font 0; the low-order bytes are an entry for font 1. Both entries are for the same character (or for characters having codes differing by 128, in the 256-character mode). In double-size mode each set of 16 chomps defines a single entry. The first 16-chomp set is loaded into the table at the entry defined by the LFA command; subsequent sets are loaded into succeeding entries.

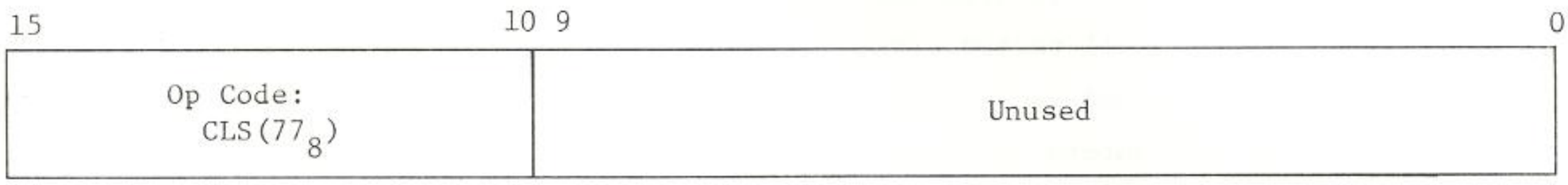
Bits 15 through 10 are the op code: 60_8.

Bits 9 through 7 are unused.

Bits 6 through 0 define the font-table entry.

Clear System (CLS)

Format:



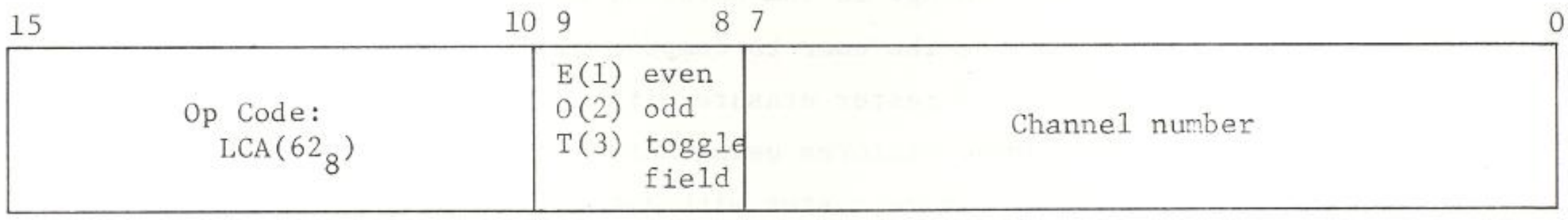
Description: CLS initializes the video disk controller.

Bits 15 through 10 are the op code: 77_8.

Bits 9 through 0 are unused.

Load Channel Address (LCA)

Format:



Description: LCA selects one of up to 256 channels on the refresh disk on which subsequent data is to be recorded. In assembly format, the LCA mnemonic is followed by a channel number and a field selection mnemonic (in that order) separated by a comma. All display information for a channel must be presented to the controller twice, once to record the odd field and once to record the even field; the LCA command selects the field as well as the channel. (The user program need send display information for a given program picture or change in a program picture only once; TMDS will then present it to the controller twice.)

Bits 15 through 10 are the op code: 62_8.

Bits 9 and 8 select the field. If the bits are 00 (no mnemonic), the field retains its previous selection; if they are 01 (E), the even field is selected; if they are 10 (O), the odd field is selected; if they are 11 (T), the field selection is changed from its previous value to the opposite selection (i.e., is toggled).

Bits 7 through 0 define the channel.

Restrictions

The refresh disk controller has a 128 data byte look-ahead, but basically it must process data that is to appear in the raster in top-to-bottom order. This implies that each new assignment of the Y-coordinate should be for a line below any line on which data bytes have been recorded by preceding commands, except for (because of the look-ahead) up to 128 of those bytes. It also implies that display information should include nothing else if it includes a full raster erase, since an erase records on the entire raster. When an LF0 or LF1 command is encountered, look-ahead is suspended until it is processed. If the controller encounters data not adhering to these restrictions, or any other restrictions mentioned above, it may suspend processing and declare the information bad. TMDS will not present bad information to the controller a second time to be recorded on the second field. Thus less than half the data in bad display information is actually recorded, and the displayed picture should be quite unsatisfactory. If the information describing a program picture is found to be bad, the user should correct the information, or debug the program that generated the information, until the information is good.

Each message containing display information sent from a user program to TMDS is presented to the controller no more than twice, once for each field. A message may define a complete picture or a change to the existing picture. The top-to-bottom restriction may therefore require the user to compose some pictures as two messages, as well as requiring that he do full raster erasure with a separate message. On the other hand, the user should not compose pictures using more messages then necessary, since it takes the same time to fill an entire raster with data as it does to alter any part of it: Using multiple messages when not needed wastes the temporal resources of both the user and the system.

Initial Conditions

When TMDS is initialized, it loads the font table with the full 192 graphic characters of extended ASCII. (The control character delete is given a displayable form.) The intended font size is 6 by 10; the characters themselves are 5 by 7 with two additional lines used for descenders. This permits up to 51 rows of 85 characters each. The intercharacter spacing is on the right and below. The codes for the control characters (other than delete) are used as a 64-character half-ASCII mini-font of size 3 by 5. Since some of these characters are in font 0 and some in font 1, use of the mini-font would usually involve changing both font sizes to 4 by 6. The complete TMDS font is shown in Fig. 5.

Before presenting the display information in a user's message to the controller, TMDS sets up a standard initial situation, which the user may always assume, by sending the following commands:

1. An LCA selecting the user's channel and the proper field;

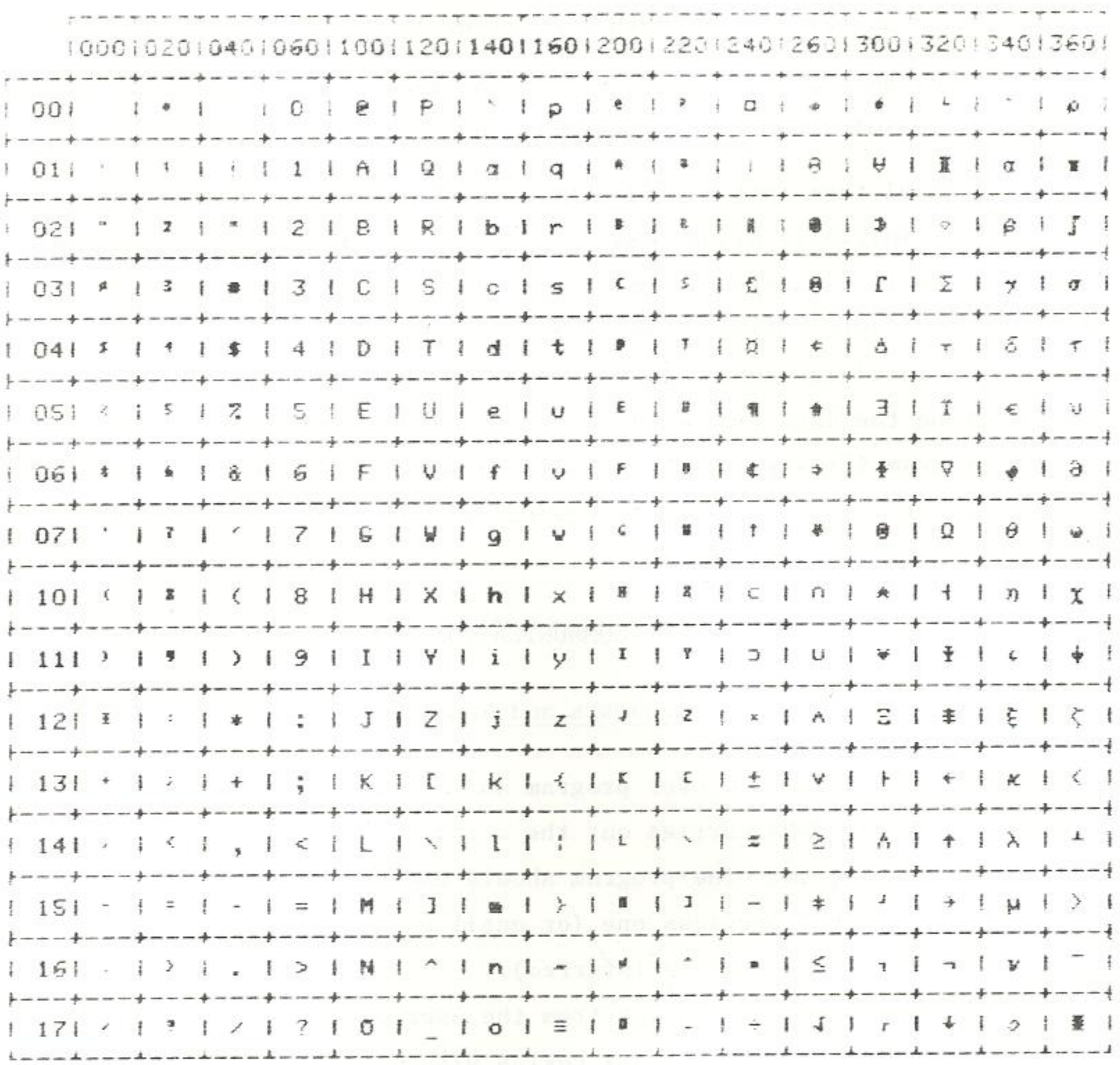


Fig. 5. The TMDS character set.

2. An LCR selecting non-swapped 256-character line replacement text mode, recorded and displayed as a positive image, not step-vertical (LCR L);

3. An LF0 and an LF1 setting both font sizes to 6 by 10 (LF0 6,10 and LF1 6,10); and

4. An LDY and an LDX setting the raster position to the upper left corner (LDY 511 and LDX 0).

A sample TMDS picture that includes the assembly language source program that produced it (on an initially blank raster) is shown in Fig. 6. The pseudo-operation DAT 's assumed to assemble data bytes, either text enclosed in double quotes (") or raster bits expressed as an octal number. An apostrophe (') marks the beginning of a comment. The statements enclosed in square brackets ([]) are not a part of the assembly language but merely describe the data that would be included at that point in the actual source program. The program illustrates several of the subtler aspects of the TMDS commands, and careful study of the picture may be rewarding.

4. USER COMMUNICATION FORMAT

Requests and Replies

Every interaction between a user program and TMDS is initiated by the program: It sends a message to TMDS; TMDS carries out the action requested (if possible) and then sends a reply to the program. The program should not send a message to TMDS until it has received a reply to the previous one (or until enough time -- several seconds -- has elapsed that a system failure may be inferred).

The text of every request (message from the user program to TMDS) and of every reply (message from TMDS to the program) begins with a three-chomp (six-byte) preface. A request may consist only of a preface or the preface may be followed immediately by display information (in the format described in Section 3). The reply to a request always contains the same preface as the request (perhaps with minor modification) followed by a three-chomp (six-byte) comment indicating the extent to which the request was carried out. The detailed format of the preface and comment is as follows:

		First byte	Last byte	
Preface	First chomp	Request code	Channel #	Appears in request and reply.
	Middle chomp	Parameter		
	Last chomp	Unused		
Comment	First chomp	Error code	Status code	Appears in reply only. Display info. may begin here in request.
	Middle chomp	Miscellany		
	Last chomp	Miscellany		

Sample
Program

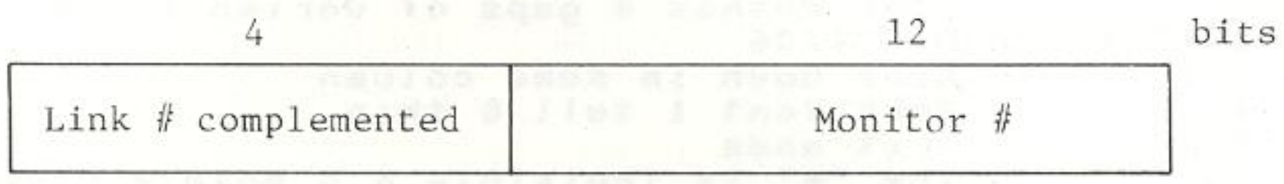
```
BXF 6           'Standard TMDS initial state assumed
DAT "Sample"
BXF 7           'New row below previous one
DAT "Program"
IDL             'This command serves no purpose
LDX 228         'Move right on new line
LCR G           'Graphic mode, still line replace
BXF 7           'Draw dashes & gaps of varied widths
DAT 23417403760077017O6
LDY 431         'Move down in same column
LF1 4,16        'Make font 1 tall & thin
LCR NIAV        'Text mode
LDD "A"         'The "A" is invisible & 4 points wide
LCR NRV         'Still negative but with background
BXF 5           'Continue to right of invisible "A"
DAT "BICID"
LCR IA          'Inverse option has no effect
BXF 5           'Continue to right of negative column
DAT "EIFIG"
LDD ":"         'New row below invisible "A"
LDY 350         'Move down
LDX 32          ' & left
LCR GNL         'Graphic mode
LDD 0           'Draw full width horizontal line
LF0 8,10        'Make both fonts of standard height
LF1 8,10        ' but wide
LCR             'Text mode, still line replace
BXF 0           'Skip a row
BXF 1020        '17 rows of 60 characters each
DAT [Here should appear the characters of the first
     17 rows of text below the long horizontal line.]
BXF 1020        '17 more rows of 60 characters each
DAT [Here should appear the characters of the last
     17 rows of text below the long horizontal line.]
```

Fig. 6. Sample TMDS picture that includes the source program describing it.

The first byte of the first chomp of the preface is the request code, indicating the type of request being made. The eight legal codes (0 through 6_8, and 377_8) are described below.

The last byte of the first chomp of the preface is the number of the refresh disk channel associated with the user making the request. This field is unused in the initial or id request by which a user asks for the assignment of a monitor and a channel (request code 0). TMDS returns the number of the assigned channel in the reply to the id request, and the same number must then be used in all subsequent requests until the monitor and channel are released. The insertion of the channel number into the reply to an id request is the only way in which the prefaces of a request and its reply ever differ.

The middle chomp of the preface is a parameter, the nature of which depends upon the type of request, as discussed below. In many cases the parameter is a link/monitor parameter as follows:



The leftmost 4 bits may be zero to indicate that no link is being selected or are the logical (ones) complement of the selected link number. That is if the field is non-zero, it should lie in the range 07_8 through 17_8, and the selected link number is found by subtracting from 17_8. However, any value less than 07 is treated as a 07 and refers to the blank channel. The rightmost 12 bits (if used) are a monitor number (not complemented) and should not exceed 777_8.

The last chomp of the preface is unused and is reserved for future expansion. Like all unused fields, it should contain zero.

The first byte of the first chomp of the comment is an error code indicating whether or not the request was honored and if not, why not. The last byte of the first chomp is a status code indicating the current status of the channel and monitor. The two remaining chomps, if used, contain miscellaneous information in regard to an error situation. Error and status codes and the nature of any additional information are described following the discussion of the various types of request.

Request Types

Id Request

The id request (code 0) is the only type of request that should be issued by a program that has not been assigned a monitor and a channel and is the only type of request in which the channel number is unused. It uses a link/monitor parameter and has one of two purposes depending upon whether or not the parameter selects a link. Except for one case, noted below, the selected monitor must be free for the request to be honored; if the monitor is busy, the reply includes the number of the associated channel.

If no link is selected (high-order four bits of the parameter are zero), then the id request is a request that the selected free monitor and an allocated channel be assigned to the user; if there is no error, the reply includes the number of the allocated channel, and the id picture appears on the monitor. If the requested monitor is not free but is already assigned to the user requesting it, the request acts just as if the monitor were free, except that an id picture appears (obliterating the current program picture) only if the protection level is changed. If a link is selected (high-order four bits of the parameter not zero), then the id request is a request that the selected link picture appear on the selected free monitor.

Confirm Request

The confirm request (code 1) conveys to TMDS the confirm number displayed on a classified id picture. The number (which should not be greater than 7777_8) is the parameter of the request. The request has no effect if the channel is already confirmed.

Bye Request

The bye request (code 2) effects the release of the assigned channel and monitor. It uses the link part (high-order four bits) of a link/monitor parameter. The newly free monitor will display the selected link picture, or, if no link is selected, the same link picture that most recently appeared on the monitor.

Link Request

The link request (code 3) uses the link part (high-order four bits) of a link/monitor parameter to specify a change in the picture on the user's monitor. If a link is selected, then the corresponding link picture appears; if no link is selected, then the program picture appears. Thus, when a link is selected, this type of request has the same effect for a monitor assigned to the user as an id request has for a free monitor or a bye request has for a monitor becoming free.

Show Request

The show request (code 4) requests that the user's program picture appear on the show link. The parameter is unused.

No-show Request

The no-show request (code 5) requests that the user's program no longer appear on the show link The parameter is unused.

Control Request

The control request (code 6) provides a way to send one chomp of display information to the refresh disk controller. Since most pictures or alterations to pictures require many chomps to describe them, this request cannot be used to compose program pictures; that is the function of the picture request described next. Rather, the control request is intended to be used to make certain simple changes to the program picture, namely, erasing it or inverting it. (Such changes could also be made with a picture request.)

That is, the single chomp should be a load control register (LCR) command with the erase (E), negative (N), and/or invert (I) options selected. (The other options would have no effect.) In fact, the only other command that acts as other than a no-operation when used alone is load data (LDD), which will place a single text character in the top left corner of the picture, erasing the balance of the top ten lines. The single command chomp is the parameter of the request; it does not follow the preface as in the case of a picture request.

Picture Request

The picture request (code 377_8) sends display information. This is the only type of request that consists of more than a preface: The display information (in the format described in Section 3) immediately follows the preface. The largest reasonable quantity of display information in a single message is slightly over 16-1/2K chomps (16K data chomps to hold 256K raster bits, 1/2K chomp to hold 512 BXF commands, and one more chomp for the LCR command selecting raster data mode); the worker computer systems and TMDS will permit a message this long (or somewhat longer) to be output in a single operation directly from the main (core) memory of a worker. The parameter of a request containing display information is not used by TMDS but is returned unchanged in the reply; it could be used by the program to contain a sequence number. Picture requests are not accepted by TMDS until confirmation is received (if necessary). Other types of requests do not require prior confirmation.

Errors

If a request is completely carried out by TMDS, then the error code in the comment is zero; otherwise, the code indicates the nature of the difficulty. The various error codes are discussed below, along with a brief message that a user program might use to convey the problem to the user at an interactive terminal. The miscellany (middle and last) chomps of the comment are unused (and contain zero) unless otherwise noted.

Transmission Hardware Failure

Code 001_8, "Transmission hardware failure." means that a request was incompletely received by TMDS or could not be transferred from one concentrator to the other (if necessary). The same kinds of hardware difficulties that cause this problem could instead cause TMDS not to receive the request at all, in which case there is no reply (since TMDS is unaware of the request); instead the request is returned to its originator as undelivered or (if the failure is more serious) lost altogether.

Display Hardware Failure

Code 002_8, "Display hardware failure." means a malfunction in the refresh disk or its controller. The picture might be partially or incorrectly recorded on the refresh disk. As with all hardware failures, the user should retry since the failure may be intermittant. If such a failure persists or becomes chronic, it should be reported promptly to computer operations personnel.

Bad Display Information

Code 003_8, "Bad display information." means that the display information in a picture request does not adhere to the restrictions (such as top-to-bottom ordering) described in Section 3. At most one field (every other line) of the picture will have been recorded on the refresh disk (which field is unpredictable). There is little point in retrying until the flaw in the display information has been corrected. In the case of this error and the previous one (errors for which display information has been partially processed), the middle chomp of the comment contains an approximate count of the number of unprocessed chomps in the display information; this may help locate the flaw in the information.

Illegal Display Command

Code 004_8, "Illegal display command." means that the display information included an illegal op code (but was otherwise all right). All display information was presented to the controller. Illegal op codes are processed as no-operations, and are therefore mainly an esthetic flaw in the display information, although perhaps a clue to other problems.

Display Buffer Overload

Code 200_8, "Display buffer overload. Retry" means that at the time a picture request arrived, TMDS had a temporary shortage of free buffer space for holding display information and therefore could not accept the display information. When the reply is received, space is then available, and the request should be repeated. The user's program should do this automatically (since the available buffer space may be gone again before the user at an interactive terminal can react). It is even more desirable that the worker computer operating system make the retry itself, in which case this error will not be seen by the user program. In any case, a message to the user is probably unnecessary.

Display Information Not Accepted

Code 371_8, "Display information not accepted." means that TMDS would not process the display information in a picture request because (a) it was too lengthy (significantly longer than 16-1/2K chomps), (b) it was received while a previous picture request was being processed, or (c) necessary confirmation had not yet been made.

Incorrect Confirmation

Code 372_8, "Incorrect confirmation." means that a confirm request contained the wrong confirm number. The monitor and channel may be released, depending upon the number of previous incorrect confirmations and the time elapsed since the id request.

Illegal Request

Code 373_8, "Illegal request." means that the request code did not have a value in the proper range.

Improper Level

Code 374_8, "Improper level." means that a required relationship among protection levels was not satisfied. Levels are associated with four items of interest:

1. Every request message has a level as determined by the worker computer operating system. TMDS views non-picture requests as decision-making requests that alter the states of monitors, links, and channels; therefore, the level of such a request should reflect the highest level that the request is allowed to influence, almost certainly the same as the level of the user program. Picture requests, on the other hand, constitute output data and do not make decisions; the level of such a request should be that of the picture defined by the display information, usually (but not necessarily) the same as the level of the user program.

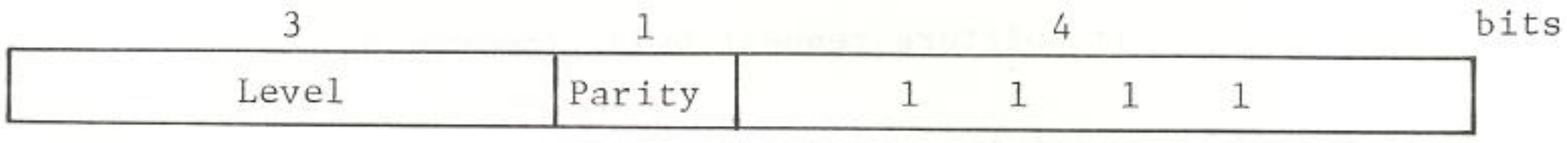
2. Every monitor has a level known to TMDS and based upon the security of the monitor's location.

3. Every link picture has a level (as given in Section 1) that reflects the level of the information in the picture.

4. An operating level is associated with every busy monitor and channel. This level is that of the id request that made the monitor busy and constitutes an upper bound to the levels of the pictures that will be displayed.

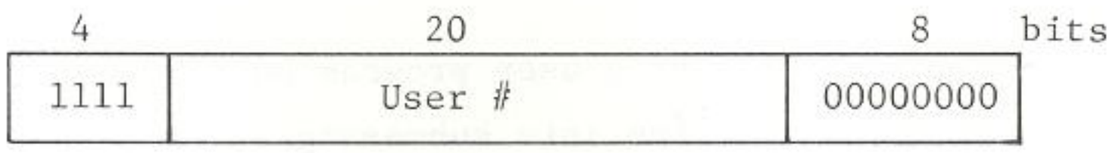
The relationships among these levels that must be satisfied are as follows: (1) The level of an id request (which may become the operating level) or of a bye or link request that selects a link must not be greater than the level of the monitor affected. (2) The level of a non-picture request must not be less than the operating level. (3) The level of a picture request must not be greater than the operating level. (4) The level of a link request, bye request, or id request that selects a link must not be less than the level of the link. (5) The level of a show request must not be greater than level a (must not be classified).

If a relationship is not satisfied, then the level with which the level of the request was compared appears in the first byte of the middle chomp of the comment. The level is indicated by the first three bits of the byte (0 = n, 1 = u, 2 = p, 3 = a, 4 = c, 5 = s, 6 = t, 7 = k); then follows a one-bit odd parity check over the level and four bits of one:



Incorrect Channel

Code 375_8, "Incorrect channel." means that the channel number appearing in a request is not that of a channel assigned to the requesting user. If the channel is not assigned to any user, then the middle and last chomps of the comment are zero. If it is assigned to another user, then these chomps contain the number of that user as a 20-bit binary number following four bits of one:



Monitor Unavailable

Code 376_8, "Monitor unavailable." means that the monitor named in an id request is not free. The channel associated with the monitor appears in the preface of the reply. The user program may therefore discover which user the monitor is assigned to by sending some non-id request (e.g., a confirm request) to the indicated channel; the user number appears in the reply (which should show error code 375). Note that monitor 000 is never free, since it is reserved for system maintenance and debugging.

Channel or Link Unavailable

Code 377_8, "Channel or link unavailable." means that no free channels were available for assignment in response to an id request (the system is saturated) or that the show link was already in use and not available for assignment in response to a show request.

Status

The status code in the comment is one of the following:

0: no monitor or channel assigned,
1: waiting for correct confirm message,
2: confirmed, no activity in progress, or
3: picture request being processed.

The sending of requests to, and the receiving of replies from, TMDS is accomplished by calls made by the user program to the operating system of its worker computer. The nature and format of these calls varies among the different kinds of worker computers and may be found in publications relating to those computers; they are not described here.

5. SYSTEM COMMUNICATION FORMAT

Requests

A request message sent to TMDS by a user program on a worker computer must be sent as a single transmission and not broken into submessages. Because of the high interactivity desired, the request should be taken directly from main (core) memory and not staged through secondary storage. Each message is preceded by a 96-bit (12-byte) heading as follows:

byte #	0	1	2	3	4	5
	Destination computer 050_8, 051_8, or 052_8	Destination device 000	Source computer (Worker #)	Source device (any value)	020_8	001_8

byte #	6	7	8	9	10	11
	Lev.	P	User #	Byte count		0

Byte 0 is the destination computer. For a request sent when the user has not been assigned a channel and monitor (request code 0), this is computer 050_8, the master concentrator. For all other requests, it depends on the channel number assigned: If the program was assigned a low channel number (0 through 177_8), requests should be directed to computer 051_8, the Lo concentrator; if the program was assigned a high channel number (200_8 through 377_8), requests should be directed to computer 052_8, the Hi concentrator. (The user program may be entrusted with deciding among these three computer numbers without endangering TMDS, but it is desirable that the selection be made by the worker system. Sending the request to the wrong computer will give rise to error code 373, "Illegal request," or 375, "Incorrect channel.")

Byte 1 is the destination device. This must be zero.

Byte 2 is the source computer. This should indicate the worker sending the message.

Byte 3 is the source device. This may be any value selected by the worker system.

Byte 4 should be 020_8 (id, bye, error, and type fields clear; binary bit set).

Byte 5 should be 001_8 (control field clear; chain bit set).

Byte 6 should contain the protection level of the user program in the three high-order bits (0 = n, 1 = u, 2 = p, 3 = a, 4 = c, 5 = s, 6 = t, 7 = k) and an odd parity check in the next bit.

The four low-order bits of byte 6 and bytes 7 and 8 should contain the binary user number. This number should be less than one million.

Bytes 9 and 10 and the seven high-order bits of byte 11 should contain a byte count of the text of the message (including the preface but not the heading). This count should not exceed about 34K.

The last bit of the last byte (byte 11) must be zero (chain bit clear). The heading is followed by the preface and (perhaps) display information provided by the user program (as discussed in Section 4).

TMDS should have plenty of buffering for messages not containing display information (request codes 0 through 6). These may be freely sent in reasonable numbers. On the other hand, buffering for display information (which may involve many more bits) is limited. All picture requests (from all user programs) should be queued by a worker and sent one at a time; a picture request should not be sent until the previous one has been successfully sent or has been discarded.

If TMDS does not receive the full heading and preface of a request (a total of 18 bytes) or if the heading format is improper, TMDS ignores the message or returns it with the error bit set. Except for these abnormal situations, every request message to TMDS gives rise to a reply message. This is true even if not all the display information following the preface was received because of hardware difficulty or lack of buffer space.

Replies

A reply always consists of a heading, preface, and comment (a total of 24 bytes). The heading has essentially the same format as that of a request, except that destination and source fields are interchanged; the byte count should always be 12. The two high-order control bits (high-order bits of heading byte 5) are used to regulate the queue of picture requests as follows:

If the high-order bit is zero, no action in regard to the queue is indicated. The reply should be sent to the user program.

If the high-order bit is one, the picture request at the top of the queue should be a request that had its heading and preface, but not its display information, sent to TMDS (the transmission being prematurely terminated because of lack of buffer space or

other failure). If the bit following the high-order bit is set, the reply is a signal to reattempt the sending of the request; this situation is associated with error code 200_8, and the reply should not be sent on to the user program. If the bit following the high-order bit is clear, the reply is a signal that the request should be discarded; this situation is associated with error codes other than 200_8, and the reply should be sent on to the program.

To provide for the possibility of TMDS failure, the worker system should have a time limit within which it expects to retry sending the top request of the queue; it should also have a limit to the number of times it will resend a request. If either limit is exceeded, the request should be discarded and an error conveyed to the user program.

Status Messages

A status message is sent to the TMDS concentrators by another Octopus computer to enable TMDS to maintain its status displays. The 48-bit (6-byte) heading is used. (Since request messages from unprivileged user programs to the TMDS must have a 96-bit heading, users cannot directly affect the status displays.) The successive 8-bit bytes of the heading are as follows:

byte #	0	1	2	3	4	5
	Destination computer 050_8	Destination device 370_8	Source computer	Source device	020_8 or 120_8	000_8

byte 0: destination computer, 050_8, the master concentrator ,

byte 1: destination device, 370_8, the status device,

byte 2: source computer,

byte 3: source device,

byte 4: 020_8 or 120_8 (binary bit and perhaps bye bit set), and

byte 5: 000_8 (no chain bit).

Following the heading, the successive 8-bit bytes of the text of the message are as follows:

byte #	0	1	2	3	4	5
	Year (0-99)	Month (1-12)	Date (1-31)	Hour (0-23)	Minute (0-59)	Second (0-59)

byte #	6	7	8	9	10
	Interface status		Field	Line	Message...

Bytes 0 through 5 define the current time. Each byte contains the value of a calendar unit (two four-byte decimal digits in the range shown above).

Bytes 6 and 7 comprise 16 interface status bits. Each bit corresponds to one network interface of the computer sending the message. The association between the bits and the interfaces may be selected to suit the computer's own system but must be reflected in tables kept by TMDS. Bits should be assigned from the left so that all unused bits are on the right. Each bit is 0 or 1 to reflect the status of the corresponding interface (down or up, respectively). Down or up is determined by whether the last message attempted to be output on the interface was successfully output.

Bytes 8 and 9 define where in the message picture a broadcast message (if any) is to be placed. If byte 8 is zero, there is no broadcast message, and the rest of the status display message is ignored. Otherwise, byte 8 defines a field in the picture within which the message is to appear. Fields in the picture include:

- A field for each worker computer, numbered with the same number as that worker,
- A field of Elephant messages, numbered 21_8,
- A field of general messages, numbered 30_8.

The field number 377_8 is taken to mean the field numbered the same as the computer sending the message; this may prove convenient in writing worker-independent programs. Note, however, that any computer may write into any field in the picture. Byte 9 defines a line within the field on which the message is to appear. Lines are numbered from top to bottom, starting with 0. Each field has a maximum number of lines, and a maximum number of characters per line, as follows:

- A field associated with a worker has 3 lines (numbered 0 through 2) of 70 characters each (it being intended that line 0 contain information supplied at deadstart and lines 1 and 2 each contain a different general broadcast).
- The Elephant message field has 3 lines (numbered 0 through 2) of 50 characters each.
- The general message field has 8 lines (numbered 0 through 7) of 70 characters each.

Following byte 9 (if byte 8 is not zero) is the broadcast message in 8-bit extended ASCII. Message bytes in excess of the display line length are ignored. The message is terminated short of the maximum if any control character is encountered, and the rest of the line is blank-filled.

Each Octopus computer is obligated to send a status message every five seconds; it should try to keep close to this interval, being neither too soon nor too late. In addition, it may send messages containing broadcasts; these should be normally far less frequent than the periodic messages. A status message is responded to with a heading-only reply if heading byte 4 is 020 (bye bit clear); the response has 010_8 ORed into byte 5 and has source and destination interchanged.

6. CONCENTRATOR OPERATION

Routing

TMDS has two concentrators (Lo and Hi, computer numbers 51_8 and 52_8). The alternate (or back-up) route to one concentrator is through the other, except that there is no alternate route for picture requests (request code 377_8). TMDS also accepts messages for computers 26_8 and 50_8 (the master concentrator). Messages for this computer should be directed to either concentrator as a primary route and to the other as an alternate route.

At any one time, one of the two TMDS concentrators is designated as the master concentrator. Only the master concentrator operates the crossbar switch which associates monitors, links, and channels and maintains the status displays. Both concentrators update program pictures. Except for messages passing through the TMDS concentrators on the way to other computers, the normal path and effect of the messages handled by TMDS is as follows:

A message for computer 26_8 (the V computer) goes to the master concentrator, changes a monitor-link association, and a reply returns to the originator (an interactive terminal concentrator).

A status message for computer 50_8 goes to the master concentrator, changes status picture records, and possibly a reply returns to the originator.

An id request message for computer 50_8 goes to the master concentrator, changes a monitor-link association, and a reply returns to the originator (a worker). Or it goes to the master concentrator, creates a monitor-channel connection (but leaves the monitor showing a link picture), goes to the concentrator controlling the channel, generates the id picture, goes back to the master concentrator, switches the id picture onto the monitor, and a reply returns to the originator (a worker).

A non-id request message for computer 51_8 or 52_8 goes to the indicated concentrator, possibly affects the program picture, if necessary goes to the master concentrator, possibly changes a monitor-link or monitor-channel connection, and a reply returns to the originator (a worker).

Interface Protocol

The status bits at the interface between a worker computer and TMDS are used much as they are with interactive terminal concentrators. The worker should expect send-permitted (ST03) to be set most of the time and receive-requested (ST04) to be set when the TMDS concentrator has a message for the worker. The worker should set send-requested STI3) when it has a message for the concentrator or receive-permitted (STI4) when it is ready to accept a message from the concentrator.

At the start of a transmission (when ST02 is set), the two software status bits controlled by TMDS (ST03 and ST04) are cleared. At the end of the transmission (when ST01 and ST02 are cleared), send-permitted (ST03) and perhaps receive-requested (ST04)

are set if the transmission was successful. Both bits (STO3 and STO4, as well as STO1 and STO2) are clear if the transmission was unsuccessful; one or both will be set again at the next interrupt (by a star bit, for example) or after 100 to 200 milliseconds.

Considerations in addition to the above apply only to picture requests, that is, to messages destined for computer 51_8 or 52_8 with a request code of 377_8. These messages normally have more than six bytes of text (in addition to twelve bytes of heading), the additional bytes being display information. In this case, after six bytes of text (the preface) have been sent, there are four cases: (a) If transmission is not terminated and the software bits are clear (STO2 set, STO3 and STO4 clear), TMDS has not yet reacted; the worker should wait. (b) If transmission is not terminated and send-permitted is set (STO2 and STO3 set), TMDS will accept the display information; the worker should continue transmission. (c) If transmission is terminated and the software bits are clear (STO2, STO3, and STO4 clear), TMDS finds the message defective and will act as though it had never been sent. (d) If transmission is terminated and send-permitted is set (STO2 clear, STO3 set), TMDS does not have sufficient buffer space; the worker should wait for a later reply which will probably indicate that transmission should be reattempted. If transmission terminates prematurely (because of hardware failure or other cause) after display information has begun to be sent, the worker should proceed as in the last of these cases, even though all status bits may be cleared.

Messages from TMDS to the worker may include interactive terminal messages moving on an alternate route as well as replies to requests to TMDS. Similarly, TMDS will accept messages to be forwarded to the interactive terminal subnetwork.

In addition to the high-speed parallel interfaces to the worker computers, TMDS has serial interfaces to the interactive terminal subnetwork. These operate by Octopus standard serial protocol and are limited to messages of 156 bytes, including heading. Picture requests, even if they do not exceed 156 bytes, cannot be sent through the serial interfaces.

Debugging Features

TMDS software provides several features to help debug TMDS hardware. These features are invoked by patching certain sentinel words in the core of the TMDS concentrators. Each sentinel word is identified here only by mnemonic, not by core address, since the address may be subject to change.

Video Mask (VMSK)

The word VMSK (video mask) is used to selectively disable and enable video refresh disks. The free channels on a disabled disk will not be assigned as busy channels; however, channels that are busy at the time of disabling will remain busy until released. Each bit of VMSK corresponds to a disk. The ordering is left to right: The high-order (leftmost) bit corresponds to the disk having channels 000 through 017,

the next bit to the disk having channels 020 through 037, and so on to the low-order (rightmost) bit, which corresponds to the disk having channels 360 through 377. A bit is set to disable the corresponding disk and cleared to enable it. All unimplemented disks should always be disabled; when TMDS is initialized, all implemented disks are enabled. VMSK is used only by the master concentrator.

The sentinel words other than VMSK all have a common format: The high-order (leftmost or sign) bit is set to activate the feature and cleared to deactivate it; when TMDS is initialized, the features are deactivated. The other bits of the high-order (left) byte are unused. The low-order (right) byte is a channel number.

Trapped Channel (TRCH)

If display information is sent to the channel selected by the word TRCH (trapped channel), the information is sent repeatedly until the feature is deactivated or another channel selected. During this time, the portion of the picture being altered will appear blank, and no display information destined for other channels on the same concentrator will be processed. Therefore, this feature should be used with caution. TRCH should be patched in the concentrator that controls the selected channel, or else it will be ignored.

Cycling Channel (CYCH)

If display information is sent to the channel selected by the word CYCH (cycling channel), then the same information is sent also to the channels of successively lower number down to and including the channel in word TRCH (or to the lowest channel -- 000 or 200 -- controlled by the concentrator). Thus the channel number in TRCH is used for both the trapped channel and the cycling channel features; however, the activation and deactivation of the cycling channel feature is determined only by CYCH. If both features are activated, the display information will be sent to one or more successive channels in reverse sequence, and then repeatedly to the last channel in the sequence. CYCH, like TRCH, should be patched in the concentrator that controls the selected channel.

Test Channel (TSCH)

Picture requests for the channel selected by the word TSCH (test channel) are honored without regard to user number or whether the channel is free. Thus any channel may be written with display information for debug purposes. TSCH, like TRCH and CYCH, should be patched in the concentrator that controls the selected channel.

Debug Channel (DCH)

The word DCH (debug channel) selects the channel that appears on the debug link; if the feature is deactivated, the debug link is blank. DCH is used only by the master concentrator.

Example

As an example of the combined use of these features, suppose that the refresh disk having channels 220 through 237 is malfunctioning. That disk is disabled by patching VMSK in the master concentrator. Then the test channel and cycling channel features are activated for channel 237 by patching TSCH and CYCH in the Hi concentrator. Also in the Hi concentrator, channel 220 is selected by patching TRCH, although the trapped channel feature is not activated. Now, by sending a picture request to channel 237, the same test pattern may be written on every channel of the malfunctioning disk. Each channel may be examined in turn on monitor 000 by patching DCH on the master concentrator.

NOTICE

"This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Energy Research & Development Administration, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately-owned rights."

Printed in the United States of America
Available from
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, Virginia 22151
Price: Printed Copy $___*; Microfiche $2.25

*Pages	NTIS Selling Price
1-50	$4.00
51-150	$5.45
151-325	$7.60
326-500	$10.60
501-1000	$13.60

JDT/gw

Technical Information Department
LAWRENCE LIVERMORE LABORATORY
University of California | Livermore, California | 94550