HFMQD6JBNs%*%Z%l!<%F%#%s%0%7%9%F%‘$H
6(D4F0:n$9$k%.%,%S%C%H%M%C%H%o!<%/

T"_7 N<B@ >>K\ >0 J?LZ 7I

El5~Bg3X Bg3X1!M}3X7O8&5f2J >pJs2J3X@l96

2f!9$OHFMQD6JBNs%*%Z%l!<%F%#%s%0%7%9%F%‘$H6(D4F0:n$9$k$3$H$rL\E*$H$7$?9bB.$+$D9b5!G=$J%.%,%S
%A%s%0%M%C%H%o!<%/$r3+H/Cf$G$"$k!#%^%k%A%f!<%6 / %^%k%A%8%g%V4D6-$K$*$1$k%f!<%64V$NDL?.$KI,M
%O!<%I%&%’%"$G<B8=$9$k$3$H$K$h$j!"DL?.%*!<%P%X%C%I$,BgI}$K:o8:$5$l!"%o!<%/%9%F!<%7%g%s%/%i%
$*$$$F$b8zN($NNI$$JBNs<B9T4D6-$rF@$k$3$H$,$G$-$k!#K\9F$G$O Sun %o!<%/%9%F!<%7%g%sMQ$K<BAu$7
%o!<%/%$%s%?!<%U%’%$%9%+!<%I$N80$H$J$k5!G=$K$D$$$F=R$Y$k!#

# Gigabit Network with Cooperative Functions for General Purpose Massively Parallel OS

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We are developping a high speed, enhanced gigabit switching network system which cooperates our general purpose massively parallel operating system. Communication overhead among user programs under multiuser/multijob environment is reduced by supporting hardware, so we can have efficient parallel execution environment on network of workstaions. We have implemented network interface hardware for Sun workstation, and describe the key functions of it in this paper.

## 1 $O$8$a$K

%o!<%/%9%F!<%7%g%sC1BN$N@-G=$,Cx$7$/8~>e$7!"<BAu$7!"%=%U%H%&%'%"$K$h$k%*!<%P%X%C%I$r:o8:$9
%9%k!<%W%C%H$N9b$$DL?.7PO)$,MxMQ2DG=$K$J$C$?:#$k!#
F|!"%o!<%/%9%F!<%7%g%s%/%i%9%?4D6-$K$*$1$kJBNs
=hM}$,8=<B$H$J$j$D$D$"$k!#JBNs%"%W%j%1!<%7%g%s
$N8zN(NI$$<B9T$N$?$a$K$O%f!<%64V$N9bB.$JDL?.
F14|$,I,MW$G$"$j!"2f!9$,3+H/Cf$ND6JBNs%*%Z%l!<
%F%#%s%0%7%9%F%` SSS–CORE $G$O!"%a%b%j%Y!<%9
DL?./F14|5!9=$r2DG=$J8B$jDc%*!<%P%X%C%I$N%=%U
%H%&%'%"$G<BAu$9$kJ}K!$rMQ$$$k [1]!#

K\9F$G=R$Y$k%M%C%H%o!<%/$O%f!<%6DL?.$N%*!<
%P%X%C%I$N$5$i$J$k:o8:$N$?$aJBNs7W;;5!>e$NJ,
;66M-%a%b%j%7%9%F%`$N<B8=$N$?$a$KDs0F$5$l$?
MBP(Memory-Based Processor) [2] $N5!G=$N0lIt
(%j%b!<%H%a%b%j%"%/%;%9!"IT2DJ,%j%b!<%H%a%b%j
%"%/%;%9!"%^%k%A%-%c%9%H!" Ack $N%3%s%P%$%K%s
%0)$r%M%C%H%o!<%/%$%s%?%U%'%$%9$K$*$$$F<B8=$9
$k$b$N$G$"$k!#

### 1.1 4XO"8&5f

%o!<%/%9%F!<%7%g%s%/%i%9%?$GJBNs=hM}4D6-$rF@
$k$?$a$N%M%C%H%o!<%/$H$7$F!" Myrinet [4] $,;HMQ
$5$l$O$8$a$F$$$k!#

Myrinet $O%9%$%C%A$H%$%s%?%U%'%$%9$+$i$J$k
%M%C%H%o!<%/$G$"$k!#%Q%1%C%H$N%X%C%@$K=q$+$l$F
$$$k7PO)>pJs$rMQ$$$F%9%$%C%A%s%0$r9T$J$&$N$G!"
1 BP 1 DL?.$N$_$r%5%]!<%H$9$k!#%$%s%?%U%'%$%9>e
$N%3%s%H%m!<%i$O%=%U%H%&%'%"$N=q$-49$($K$h$C$F
G$0U$N%W%m%H%3%k$N%Q%1%C%H$r07$&$3$H$,2DG=$G$"
$k!#%$%s%?%U%'%$%9>e$N%P%C%U%!$O%f!<%6$N%"%I%l
%96u4V$+$i%"%/%;%92DG=$G$"$j!"Aw<u?.:]$N%G!<%?
$N%3%T!<2s?t$r:o8:$G$-$k!#

## 2 %O!<%I%&%'%"$K$h$k;Y1g

### 2.1 SSS–CORE $N%a%b%j%Y!<%9DL?.5!9=

%^%k%A%f!<%6/%^%k%A%8%g%V4D6-$K$*$$$F$O!"3F%b%j%P%j%"$O Acknowledge(Ack) %Y!<%9$G<B8=$5
%W%m%;%9$K$H$C$F%"%I%l%96u4V$,2>A[2=$5$l$F$$$l!" non-blocking $N<jB3$-$GF14|40N;$+H]$+$N7k
$k!#J88% [2] $K=R$Y$i$l$F$$$k$h$&$K!"%f!<%64V$N2L$O%U%i%0$KJV$5$l!" Snoopy Spin wait [3] $G$=
DL?.$r7Z$/$9$k$3$H$O!"2>A[2=$5$l$?%j%b!<%H%a%b$N%U%i%0$rMxMQ$9$k!#
%j$X$N%"%/%;%9$rJ*M}%l%Y%k$NDL?.<jCJ$K%^%C%T %Q%1%C%H$NE~Ce@h$G%"%/%;%9@h%W%m%;%9$,%9%1
%s%0$9$k3%9%H$r$$$+$K:o8:$G$-$k$+$K$+$+$C$F$$%8%e!<%k$5$l$F$$$k>l9g$K$O!"%"%/%;%9@h%"%/%;%9
$k!# ID $rHf3S$9$k!#0lCW$9$l$P%"%/%;%9$O5v2D$5$l$k

2>A[2=$5$l$?%j%b!<%H%a%b%j%"%/%;%9$N<B8=$K$N$G!"2>A[%"%I%l%9$+$iJ*M}%"%I%l%9$r0z$-%"%/
$O!" (1) Aj<j@h$N%N!<%I ID $+$iDL?.O)$r7hDj$9$k %;%9$r9T$J$&!# (%Z!<%8=hM}$N;~E@$G!"%j%b!<%H%a
5!9=!" (2) M?$($i$l$?%M%C%H%o!<%/%"%I%l%9$+$iJ*%b%j%"%/%;%9$5$l$k2DG=@-$N$"$k2>A[%"%I%l%9$H

M}%Z!<%8$r7hDj$9$k5!9=!" (3) %"%/%;%9$K4X$9$k%W
%m%F%/%7%g%s$rD4$Y$k5!9=!"$,I,MW$G$"$k$,!"2f!9
$N%M%C%H%o!<%/$G$O0J2<$N$h$&$K$O!<%I%&%'%"$G

1. Aj<j@h$N%N!<%I ID $N$_$GDL?.O)$r7hDj

   %Z!<%8$N0\F0$d%^%$%0%l!<%7%g%s$r%f!<%6$+
   $i2>A[2=$9$k$?$a$K!"DL?.Aj<j@h$N%N!<%I ID
   $r%f!<%6$K$H$C$F2>A[2=$9$kI,MW$,$"$k!#

   2f!9$N%M%C%H%o!<%/$N%9%$%C%A%s%0%N!<%I$G
   $O%Q%1%C%H$K%M%C%H%o!<%/$N7PO)$,=q$+$l$F
   $$$kI,MW$,$"$j!"%$%s%?%U%'%$%9$+!<%I$N%3
   %s%H%m!<%i$OAj<j@h$N2>A[%N!<%I ID $+$i7P
   O)$r7hDj$9$k$?$a$N%F!<%V%k$r;}$D!#%F!<%V
   %k$K%R%C%H$7$J$+$C$?>l9g$O OS $K3d9~$_$r
   $+$1%=%U%H%&%'%"$G2r7h$9$k!#

2. %M%C%H%o!<%/%"%I%l%9$+$iJ*M}%Z!<%8$r7hDj

   SSS–CORE $G;HMQ$7$F$$$k%M%C%H%o!<%/%"
   %I%l%9$O!"%W%m%;%9 ID $H$=$NCf$G$N2>A[%"
   %I%l%9$rAH$K$7$?$b$N$G$"$k!#:#2s%M%C%H
   %o!<%/%$%s%?%U%'%#%9$r<BAu$7$? SBus $G$O
   2>A[%"%I%l%9$K$h$k%"%/%;%9$,2DG=$J$N$G!"
   %Q%1%C%H$,E~Ce$7$?%3%s%H%m!<%i$G%W%m%;%9
   ID $NHf3S$r9T$J$$!"0lCW$9$l$P2>A[%"%I%l%9
   $G%"%/%;%9$9$k!#

3. %W%m%F%/%7%g%s

   SSS–CORE $G$O%W%m%;%9BP$7$F%"%/%;%9 ID
   $,MQ0U$5$l$F$$$F!"%"%/%;%9 ID $,<hF@$G$-
   $?%W%m%;%9$KBP$7$F%j%b!<%H%a%b%j%"%/%;%9
   $,<B9T2DG=$G$"$k!#%"%/%;%9 ID $r<hF@$9$k
   $?$a$K$O!"<+J,$N%W%m%;%9 ID $H%"%/%;%9 ID
   $rB>?M$KDLCN$9$kI,MW$,$"$k!#

%j%b!<%H%a%b%j%"%/%;%9$N=g=x4IM}$K$O4KOB$5$l
$?%a%b%j%b%G%k$r;HMQ$7!"I,MW$K1~$8$F%9%l%C%I$,
%a%b%j%P%j%"$rD%$k$3$H$G=g=x$U$1$,$J$5$l$k!#%a

J*M}%"%I%l%9$NBP1~$r%3%s%H%m!<%i$N TLB $K=q$$$F$*$/$3$H$,I,MW!#:#2s%$%s%?%U%'%$%9$r:n@.$7$?SBus $G$O2>A[%"%I%l%9$G%"%/%;%9$,2DG=$J$N$G!"TLB $OITI,MW!#) @.8y$7$?>l9g!"$9$Y$F$N=hM}$O%O!<%I%&%'%"$G9T$J$o$l%=%U%H%&%'%"%*!<%P%X%C%I$OB8:_$7$J$$!#

1. %"%I%l%9JQ49$,<:GT$7$?>l9g

   OS $,J*M}%Z!<%8$r3dEv[1]$F%G!<%?$rE>Aw$9$k!#

2. %"%/%;%9 ID $,01CW$7$J$$>l9g

   OS $OIT@5$J%"%/%;%9$r9T$J$C$?%W%m%;%9$N%W%m%;%9 ID $H%"%/%;%9 ID $r%f!<%6$KDLCN$9$k!#Aj<j$N%"%/%;%9 ID $r<j$KF~$l$?%f!<%6$O%7%9%F%`%3!<%k$K$h$jAj<j$N%W%m%;%9$rDd;_$G$-$k!#%Q%1%C%HF~$C$F$$$k%"%/%;%9H/9T85$N%W%m%;%9 ID $H%"%/%;%9 ID $O%f!<%6$,2~cb$G$-$J$$$h$&$K$9$k$?$a!"Aw?.85$N%3%s%H%m!<%i$,Aw?.%Q%1%C%H$N%X%C%@$K%O!<%I%&%'%"$G=q$-9~$`!#

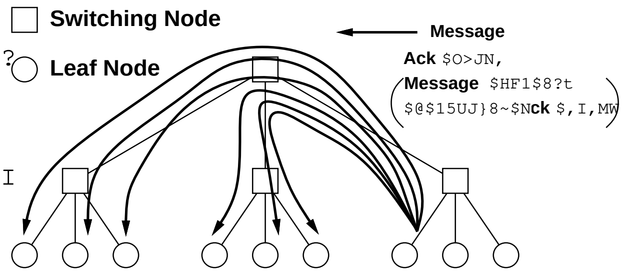
3. %W%m%;%9 ID $,01CW$7$J$$>l9g

   OS $,$=$N%W%m%;%9$NO@M}%"%I%l%9$r2r7h$7!"Ev3:%Z!<%8$r3dEv$F$F%G!<%?E>Aw$r$*$3$J$&!#

%a%C%;!<%8Aw?.$N:]$K%3%s%H%m!<%i$K%W%m%;%9 ID $H%"%/%;%9 ID $r=q$-9~$`J}<0$r:NMQ$9$k$H!"%f!<%6$,$=$l$i$r2~cbIT2DG=$K$9$k$K$O OS $N%7%9%F%`%3!<%k$r8F$VI,MW$,$"$jM>7W$J%*!<%P!<%X%C%I$,2]$;$i$l$k$N$G!"%3%s%F%/%9%H%9%$%C%A$N:]$K=q$-9~$`J}<0$r:NMQ$7$?!#$=$N$?$a!"%3%s%H%m!<%i$,FH<+$N TLB $r;}$?$J$$:#2s$N<BAu$G$O!" Sun SPARCstation 20 $N$h$&$K%o!<%/%9%F!<%7%g%s$KJ#?t$N%W%m%;%C%5$,B8:_$9$k>l9g$K$*$$$F$b%j%b!<%H%a%b%j%"%/%;%9$r;HMQ$G$-$k%W%m%;%C%5$O0l$D$K8BDj$5$l$k$H$$$&@)Ls$,2]$;$i$l$k!#

%j%b!<%H%a%b%j%"%/%;%9$, Ack $rI,MW$H$9$k>l9g!" Ack $,5"$C$F$-$?$3$H$rD4$Y$k$?$a$N SS–Wait %U%i%0$N%M%C%H%o!<%/%"%I%l%9$r%Q%1%C%H$KF~$l$FAw?.$9$k!#$3$N%Q%1%C%H$r<u?.$7$?%N!<%I$O!"%j%b!<%H%a%b%j%"%/%;%9$r=hM}$7$?8e$GAw?.85$K Ack

[1] <BAu$N:Y$+$$OC$7$K$J$k$,!" SBus [5] $G$O%j%/%(%9%H$N$"$C$?2>A[%"%I%l%9$KBP$7$FJ*M}%Z!<%8$,B8:_$7$J$$>l9g!"Translation Phase $G Rerun Acknowledge $r@8@.$7!"$=$N4V$KJ*M}%Z!<%8$rMQ0U$9$k$3$H$b2DG=$G$"$k!#




?^ 1: 1 BP 1 DL?.$r;HMQ$7$?%^%k%A%-%c%9%H

$rJVAw$9$k!# Ack $NJVAw$O Ack $J$7$N%j%b!<%H%a%b%j%i%$%H$G<BAu$5$l$k!#

0J>e$r$^$H$a$k$H!"%j%b!<%H%a%b%j%"%/%;%9%Q%1%C%H$r=hM}$9$k$?$a$K%3%s%H%m!<%i$KI,MW$J>pJs$O0J2<$NDL$j$G$"$k!#

- %Q%1%C%H$N7?
- Aj<j@h$N%M%C%H%o!<%/%"%I%l%9 (Aj<j@h$N%W%m%;%9 ID $H2>A[%"%I%l%9)
- Aj<j@h$N%"%/%;%9 ID
- Aj<j@h$N%N!<%I ID
- %G!<%?$N@hF,HVCO
- %G!<%?$N%5%$%:
- <+J,$N%W%m%;%9 ID
- <+J,$N%"%/%;%9 ID

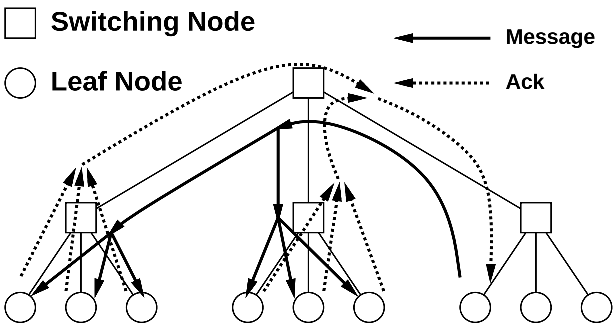
## 2.2 %A%'%$%K%s%0$K$h$k%^%k%A%-%c%9%H

%9%1!<%i%V%k$J%M%C%H%o!<%/$OJ*M}E*$K3,AX9=B$$r$7$F$$$k>l9g$,B?$$!#%/%i%9%?!<$rN%$l$l$PN%$l$k$[$I (3,AX$N>eJ}$G$N%M%C%H%o!<%/$N%P%s%II}$,Bg$-$/$J$$$8B$j) DL?.$N%9%k!<%W%C%H$,2<$,$k$N$G!"N%$l$?%/%i%9%?!<4V$NDL?.$N:o8:$,I,MW$G$"$k!# 1 BP 1 $NDL?.$G$"$l$P$*8_$$$r6a$/$K%9%1%8%e!<%j%s%0$9$l$PNI$$$,!"B??M?t$KBP$7$F%^%k%A%-%c%9%H$rH/@8$5$;$k$H!"?M?t$K1~$8$FN%$l$?%/%i%9%?$KBP$9$kDL?.$,A}2C$9$k!#

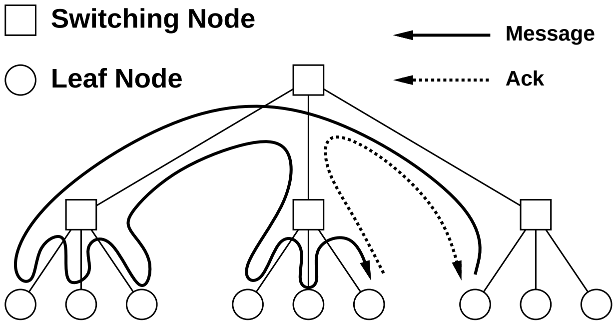
1 BP 1 DL?.$7$+%5%]!<%H$7$J$$%M%C%H%o!<%/$G$O!"C1=c$KN%$l$?%/%i%9%?$N?t$@$1$NDL?.$,I,MW$H$J$k!#

J*M}%M%C%H%o!<%/$,3,AXE*$G$"$l$P!"%9%$%C%A%s%0%N!<%I$K$*$$$FF~NO@h$N%Q%1%C%H$r%3%T!<$7$FJ#?t$N=PNO@h$K=PNO$7!"3,AX$N>e$NJ}$GI,MW$J%P%s%II}$rBP?tE*$KM^$($k$3$H$,2DG=$G$"$k!#

%9%$%C%A%s%0%N!<%I$K$=$N$h$&$J5!G=$,$J$$>l9g!"$^$?$O%M%C%H%o!<%/$NJ*M}9=B$$,3,AXE*$G$J$$>l9g$N$?$a!"%A%'%$%K%s%0$K$h$k%^%k%A%-%c%9H




?^ 2: 3,AX%^%k%A%-%c%9%H




?^ 3: %A%'%$%K%s%0$K$h$k%^%k%A%-%c%9%H

$N5!G=$r%$%s%?!<%U%'%$%9%+!<%I$K;}$?$;$k!#%$%s%?%U%'%$%9%+!<%I$O<u$1<h$C$?%Q%1%C%H$r<+J,$N<u?.%P%C%U%!$K%9%H%"$9$k$HF1;~$K!"B>?M$K%U%)%o!<%G%#%s%0$9$k5!G=$r;}$D!#%M%C%H%o!<%/$,3,AXE*$J>l9g!"3,AX%^%k%A%-%c%9%H$KHf3S$7$FI,MW$J%P%s%II}$O 2 G\$K$J$k$?$a!"F1MM$KBP?tE*$KM^$($k$3$H$,2DG=$G$"$k!#

%^%k%A%-%c%9%H$, Ack $rI,MW$H$9$k$J$i$P!"%Q%1%C%H$K<+J,$N Ack $b$D$1$F%U%)%o!<%G%#%s%0$9$k!#$=$7$F!"%^%k%A%-%c%9%H$N%Q%1%C%H$r<u$1<h$k:G8e$N%N!<%I$,$^$H$^$C$? Ack $rAw?.@h$KJVEz$9$k!#I,MW$J%P%s%II}$O Ack IU$-$N3,AX%^%k%A%-%c%9%H$HF1$8$G$"$k!#

3,AX%^%k%A%-%c%9%H$H%A%'%$%K%s%0$K$h$k%^%k%A%-%c%9%H$G$O%Q%1%C%H$,DL$k7PO)$,0[$J$k$N$G!"%X%C%@$K7PO)>pJs$rF~$1$k>l9gA*Br$9$k%^%k%A%-%c%9%H$N<oN`$K$h$C$F%X%C%@$,0[$J$k!#%9%$%C%A%s%0%N!<%I$K$*$$$F$3$N 2 <oN`$N%X%C%@$N4V$NJQ49$O2DG=$G$"$k!#%$%s%?%U%'%$%9%N!<%I$G$O%A%'%$%K%s%0$K$h$k%^%k%A%-%c%9%H$r3,AX%^%k%A%-%c%9%H$KJQ49$G$-$k$,[2]!"5U$r9T$J$&$K$O%Q%1%C%H$NAw?.85$X$N7PO)>pJs$,<:$o$l$F$$$J$$$3$H$,I,MW$G$"$k!#

## 2.3 %j%b!<%H%a%b%j$KBP$9$kIT2DJ,A`:n

0lO"$NIT2DJ,A`:nNs$rAj<j@h%f!<%6$KAw?.$7$F<B9T$9$l$P!"DL?.$HF14|$N%Q%1%C%H$r8:>/$5$;$k$3$H$,2DG=$G$"$k!#$5$i$K!"4JC1$JIT2DJ,A`:n (Read-Modify-Write, Compare-and-Swap) $r%O!<%I%&%'%"$G%5%]!<%H$9$k$H%*!<%P%X%C%I$,8:>/$9$k!#

%$%s%?%U%'%$%9%+!<%I$K1i;;4o$r<BAu$7!" I/O %P%9[3]$KMQ0U$5$l$F$$$k%"%H%_%C%/%H%i%s%6%/%7%g%s$rMxMQ$7$FIT2DJ,A`:nMW5a%Q%1%C%H$r=hM}$9$k!#

## 3 <BAu

## 3.1 %9%$%C%A%s%0%N!<%I

2f!9$,9=C[Cf$N%M%C%H%o!<%/$O%9%1!<%i%V%k$J%9%$%C%A%s%0%M%C%H%o!<%/$G$"$j!"0J2<$N@)Ls$rK~$?$9I,MW$,$"$k!#

- %9%k!<%W%C%H$,9b$$
- %M%C%H%o!<%/$NJ*M}9=B$$r2>Dj$7$J$$
- I,MW$J>l9g$K FIFO @-$,F@$i$l$k
- %Q%1%C%H$rMn$5$J$$
- %(%i!<D{@5$,$"$k

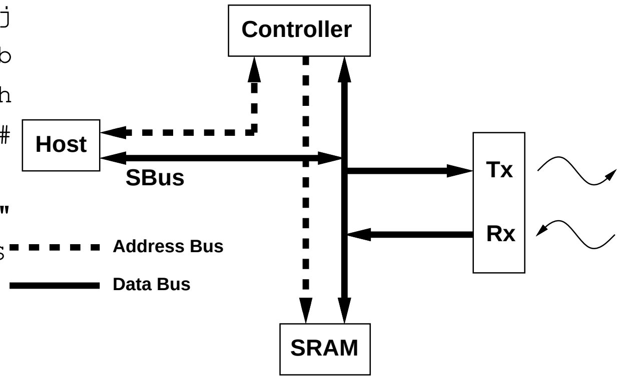
$3$l$i$9$Y$F$NLdBj$r2r7h$9$k$?$a!"%X%C%@$K7PO)>pJs$rF~$l$F$*$-!"%9%$%C%A$G%P!<%A%c%k%+%C%H%9%k!<$r9T$J$&!# Myrinet $H0[$J$j!"A0=R$N3,AX%^%k%A%-%c%9%H$d Ack $N%3%s%P%$%K%s%0$r%9%$%C%A%s%0%N!<%I$G=hM}$9$kI,MW$,$"$k$N$G!"%Q%1%C%H$N7?$K4X$9$k>pJs$r%X%C%@$N@hF,$KF~$l$kI,MW$,$"$k!#

%P!<%A%c%k%+%C%H%9%k!<$O<u?.%]!<%H$+$iAw?.%]!<%H$K%G!<%?$,%U%)%o!<%I$G$-$J$$>l9g$K$O%9%H%"%"%s%I%U%)%o!<%I$K@ZBX$($k$?$a!"Aw?.%]!<%H$KBP$7$F<u?.$,2DG=$G$"$k$3$H$rCN$i$;$k$?$a$N%U%m!<@)8f$,I,MW$G$"$k!#%Q%1%C%H$NAw?.Cf$K%U%m!<@)8f$r9T$J$&$H!"%H%i%s%7!<%P$NAw?.O)$H<u?.O)$rF1;~$K;HMQ$9$k$N$G%M%C%H%o!<%/$N%9%k!<%W%C%H$rH>8:$7$F$7$^$&!#%Q%1%C%H$,<u?.$G$-$k$3$H$r$"$i$+$8$aCN$i$;$F$*$-!"%Q%1%C%H$NE>Aw$rESCf$GCf$7$J$$$h$&$K$9$k$K$O!"0lEY$KE>Aw$G$-$k%Q%1%C

[2] 3,AX%^%k%A%-%c%9%H$r%5%]!<%H$9$k$?$a$K==J,$J5!G=$r;}$D%9%$%C%A%s%0%N!<%I$G$O$3$NJQ49$r<B8=$G$-$k$N$G!"%$%s%?%U%'%$%9%N!<%I$G<B8=$9$kI,MW$O$J$$!#

[3] PCI [6] $G$O!" LOCK# ?.9fEy$r;HMQ$9$k!# SBus $K4X$7$F$O!" IEEE1496 I8=`$+$i$O:o=|$5$l$?$,!" SBus Specification B.0 $K$OB8:_$7$F$*$j!" SBus $rM#0l<BAu$7$F$$$k$H$$$C$F$$$$ Sun $N%o!<%/%9%F!<%7%g%s$K$O%"%H%_%C%/%H%i%s%6%/%7%g%s$OB8:_$7$F$$$k!#

%H$NBg$-$5$r@)8B$9$kI,MW$,$"$k!#$^$?!"Aw?.$,%j
%b!<%H%i%$%H$N>l9g!"%Q%1%C%H$N%G!<%?$,%Z!<%8Fb
$K<}$^$C$F$$$J$$$H<u?.B&$G$O0l$D$N%Q%1%C%H$N=h
M}Cf$KB0@-$N0[$J$k%Z!<%8$r=hM}$9$kI,MW$,$"$k!#
(SBus $G$J$$>l9g!"2>A[%"%I%l%9$+$iJ*M}%Z!<%8$r
0z$/:n6H$r%Q%1%C%H=hM}Cf$KJ#?t2s9T$J$&I,MW$,$"
$k!#)0J>e$NM}M3$K$h$j!"%Q%1%C%HFb$N%G!<%?%5%$
%:$O:GBg 4KB $H$7!"%Z!<%86-3&$rD6$($J$$$H$$$&
@)Ls$r$D$1$k!#




?^ 4: %V%m%C%/%@%$%"%0%i%`

### 3.2 %M%C%H%o!<%/%$%s%?%U%'%$%9

SBus %+!<%I$H$7$F%M%C%H%o!<%/%$%s%?%U%'%$%9 $r:n@.$7!" Sun SPARCSation20 $G;HMQ$7$F$$ $k!#;29M$^$G$K!"=i$a$K3F5!G=%V%m%C%/$N%9%k!< %W%C%H$r<($9!#

8w%H%i%s%7!<%P$O 53.125MHz $r 1 %5%$%/%k$H$7!" 3F%5%$%/%k$K 20[4]$N%G!<%?$rAw<u?.$G$-!"$=$l $>$l 1.0625Gb/s $N%9%k!<%W%C%H$r;}$D!#%G!<%?$O 8b $r 10b $K%(%s%3!<%I (!V8B10B!W [7]) $7$FE>Aw $5$l$k$N$G!"<B:]$KE>Aw$5$l$k%G!<%?$O 16b/ %5%$ %/%k$G$"$j!" 850Mb/s $G$"$k!#

SBus $N3HD%E>Aw$O%5%]!<%H$7$J$$!# 25MHz F0 :n$N SBus $G$O 1 %5%$%/%k$K 32b $N%G!<%?$rE>Aw 2DG= (100MB/s) $G$"$k!#

SS10/20 $G%5%]!<%H$5$l$F$$$k%P!<%9%H$N:GBg%5 %$%/%k?t$O 8(32B E>Aw) $J$N$G!"%W%m%H%3%k$KI,MW $J%5%$%/%k$r2C$($k$H 67MB/s $N%9%k!<%W%C%H$G $"$k$,!"%P%9$OJ#?t$N%G%P%$%9$K$h$j6&M-$5$l$k$N $GDj>oE*$K 67MB/s $H$O8B$i$J$$!#$^$?!"0lHLE* $K%j%"%k%?%$%`$G I/O %P%9$rMxMQ$G$-$k$H$O8B$i $J$$$N$G!"%9%k!<%W%C%H$N9b$$Aw<u?.%P%C%U%!$rMQ 0U$9$kI,MW$,$"$k!#

Aw<u?.%P%C%U%!$H$7$F%i%$%H%5%$%/%k$, 20nS (50MHz) $N SRAM(512K×8b) $r;HMQ$7$?!# 32b $N %G!<%?%P%9$r3NJ]$9$k$K$O 4 8D$N SRAM $,I,MW$G $"$j!"$3$N>l9g$N%9%k!<%W%C%H$O (20nS $K 4b $J$N $G) 200MB/s $G$"$k!#Aw<u?.%P%C%U%!$O%j%s%0 %P%C%U%!$H$7$F;HMQ$7!"%O!<%I%&%'%"$K$h$k4IM}5! 9=$rC1=c$K$9$k!#

### 3.3 Aw?.

$^$:%X%C%@$N0lIt$r SRAM $K=q$-9~$_!"%3%s%H %m!<%i$NAw?.MW5a%l%8%9%?$K%G!<%?=q$-9~$`!#$=$N 8e!"%3%s%H%m!<%i$O%P%9$rDL$7$F%[%9%H$+$i%G!<%? $r SRAM $KE>Aw$7!" CRC $r7W;;$9$k!#%j%b!<%H %a%b%j%"%/%;%9$G$O!"%G!<%?$,%Z!<%8$N6-3&$rD6$( $J$$$3$H$rAw<u?.$NN>J}$G%A%'%C%/$9$k!#Aw?.@h$N 2>A[%N!<%I ID $+$i7PO)$r5a$a$F%X%C%@$r9=C[$7!" %G!<%?$rAw?.$9$k!#

### 3.4 <u?.

%Q%1%C%H$N$H$j$3$\$7$rKI$0$?$a!"%H%i%s%7!<%P $+$i$N<u?.%G!<%?$r%*%s%\!<%I$N SRAM $K=q$-9~ $`A`:n$O$9$Y$F$NAw<u?.$K4X$o$k%G!<%?E>Aw$NCf$G 0lHVM%@hEY$,9b$$!#<u?.$OE~Ce=g$K=hM}$9$k!#

<u?.%G!<%?Fb$N%W%m%;%9 ID $H%"%/%;%9 ID $rH4 $-$@$7!"%W%m%;%C%5$K8=:_%9%1%8%e!<%k$5$l$F$$ $k%W%m%;%9$N%W%m%;%9 ID $H%"%/%;%9 ID $HHf3S$9 $k!#N>J}$H$b0lCW$7$?>l9g$K$O!"2>A[%"%I%l%9$N JQ49$r SBus $K%j%/%($9%H$7!"@.8y$9$l$P DMA $G %G!<%?$rE>Aw$9$k!#<:GT$7$?>l9g!" OS $KBP$7$F3d 9~$r$+$1!"860x$K1~$8$?BP=h$r9T$J$&!#

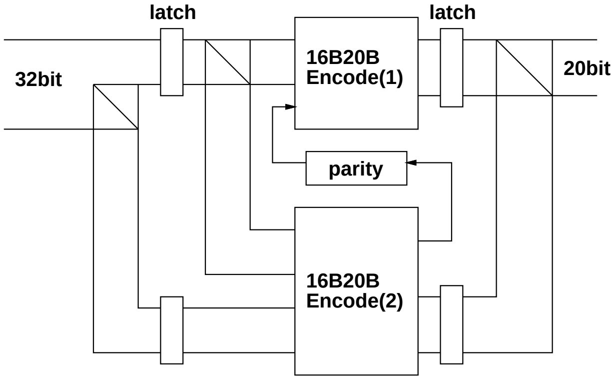
### 3.5 5!G=%V%m%C%/

%3%s%H%m!<%kIt!"%H%i%s%7!<%P!"Aw?.%G!<%?%(%s %3!<%IIt!"<u?.%G!<%?%G%3!<%IIt!"Aw<u?.%P%C%U%! $+$i$J$k!#

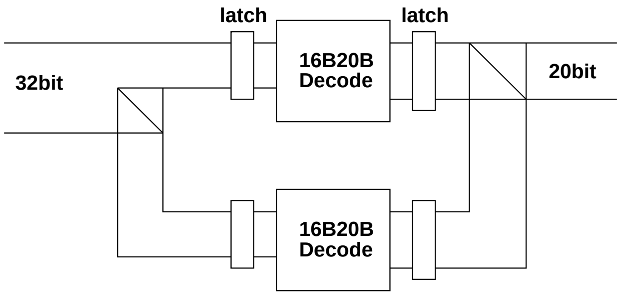
%3%s%H%m!<%iItJ,$O DMA E>Aw2sO)!"IT2DJ,A`:n $N$?$a$N1i;;4o!"%W%m%;%9 ID $d%"%/%;%9 ID $rHf 3S$9$k$?$a$NHf3S4o!"2>A[%N!<%I ID $+$i7PO)>pJs $X$N%k%C%/%"%C%W%F!<%V%k$r;}$D!#

Hf3SE*DcB.$GF0:n$9$k FPGA $G!"Ls 18.8nS $N %5%$%/%k$G%G!<%?$r%(%s%3!<%I$9$k$3$H$OIT2DG=$G $"$k!#$3$N$?$a!"%(%s%3!<%I$N2sO)$O 2 %;%C%HMQ0U $7!" 32b $rLs 37nS $G%(%s%3!<%I$9$k$3$H$H$7$?!# (16b $N%G!<%?$O<B:]$K$O 5b,3b,5b,3b $N%V%m%C%/ $KJ,3d$5$l$F$$$F!"%V%m%C%/Kh$K7W;;$7$?%Q%j%F%#

[4] 20 %S%C%H$N0UL#!#0J2<!"FC$K;XDj$7$J$$8B$j 'b' $O%S%C%H $rI=$7!" 'B' $O%P%$%H$rI=$9!#




?^ 5: %(%s%3!<%I2sO)




?^ 6: %G%3!<%I2sO)

$r85$K<!$N%V%m%C%/$r7W;;$9$k!#%Q%j%F%#$r%W%m%Q%2!<%H$7$J$$$?$a$K$O!" 32b $N:G8e$N%V%m%C%/$G$O!"<jA0$N 29b $r 1 %S%C%H$K%(%s%3!<%I$9$kI,MW$,$"$k!#)

<u?.$bF1MM$K 1 %/%m%C%/$G 20b $N%G!<%?$r<u$1<h$k!#$3$1$r%3%s%H%m!<%iFb$N%1%8%9%?$K%i%C%A$7!" 2 %/%m%C%/Kh$K 32b $N%G!<%?$K%G%3!<%I$7$F SRAM $K=q$-9~$`!#

%5$$%: 4B %j%b!<%H%a%b%j%i%$%H$r9T$J$&>l9g!"I,MW$J%X%C%@$H%F%$%i$O 30B+2B×n(ESCf$N%9%$%C%A$N?t) $G$"$j!"%9%$%C%A$r 1 8D7PM3$9$k%[%9%HF1;N$NDL?.$G$ODL?.7PO)$N;HMQ8z$N(G$Kh IC 24M 8D$N%Q%1%C%H$r=hM}2DG=$G$"$k!#

## 4 $*$o$j$K

2f!9$OHFMQD6JBNs OS $H6(D4F0:n2DG=$J%.%,%S%C%H%M%C%H%o!<%/$r9=C[Cf$G$"$j!"$=$N$?$a$N%M%C%H%o!<%/%$%s%?!<%U%'%$%9%+!<%I$r SPARCStation20 $N SBus >e$K<BAu$7$?!#$3$N%M%C%H%o!<%/%$%s%?!<%U%'%$%9%+!<%I$O9b$$%9%k!<%W%C%H$r;}$A!"%a%b%jX$N=q$-9~$_J]8n$r%O!<%I%&%'%"$G%5%]!<%H$7$F$$$k$N$G!"%f!<%6$K$h$kDL?.$rDc%1%$%F%s%7$G<B8=$9$k!#

:#8e!"%M%C%H%o!<%/$N%9%$%C%A%N!<%I$r<BAu$7!"%o!<%/%9%F!<%7%g%s%/%i%9%?$r9=C[$7$F<B83$r$7!"D6JBNs OS $H$N6(D4F0:n$N8!>Z$r9T$J$&M=Dj$G$"$k!#

<U<-

K\8&5f$O>pJs=hM}?66=;v6H2q!J#I#P#A!K$,<B;\$7$F$$$kFHAOE*>pJs5;=Q0i@.;v6H$N0l4D$H$7$F9T$J$O$?!#

;29MJ88%


[1] >>K\ >0, J?LZ 7I, "HFMQD6JBNs%*%Z%l!<%F%#%s%0%7%9%F%`SSS–CORE $N%a%b%j%Y!<%9DL?.5!G=", >pJs=hM}3X2q Bh 53 2sA49qBg2q (September 1996)

[2] >>K\ >0, J?LZ 7I, "D6JBNs7W;;5!>e$N6&M-%a%b%j%"!<%-%F%/%A%c", ?.5;Js, CPSY92-96, pp.47–55 (August 1992)

[3] >>K\ >0: "%^%k%A%W%m%;%C%5>e$NF14|5!9=$H%W%m%;%C%5%9%1%8%e!<%j%s%0$K4X$9$k9M;!", 7W;;5!%"!<%-%F%/%A%c8&5f2qJs9p No.79-1, >pJs=hM}3X2q, pp.1–8 (November 1989)

[4] Nanette J. Boden, Danny Cohen, Robert E. Felderman, Alan E. Kulawik, Charles L. Seitz, Jakov N. Seizovic, and Wen-King Su: "Myrinet – A Gigabit-per-Second Local-Area Network", *IEEE-Micro*, Vol.15, No.1 pp.29–36 (February 1995)

[5] Susan A. Mason: "SBus Handbook", *Sun Microsystems, Inc.* (1994)

[6] Tom Shanley, Don Anderson: "PCI System Architecture 3rd edition", *MindShare, Inc.* (1995)

[7] A. X. Widmer, P.A. Franaszek: "A DC Balanced, Partitioned Block, 8B10B Transmission Code", *IBM Journal of Research and Development*, Vol.27, No.5 (September 1983)