%\%j%e!<%`%l%s%@%j%s%0@lMQJBNs7W;;5! *ReVolver*/**C40** $N@-G=I>2A

5H C+ D> <y[†] =E ED Bg =u[††] 8^ Eg @5 M5[††]
?9 bC 0l O:[††] IY ED bC <#[††]

ReVolver/C40 $O!"3 DN%9%F!<%8Kh$k%^%/%m%Q%$%W%i%$%s9=@.!"3F%9%F!<%8K*1kMM!9$JJBNs=hM}!"%P%s%/%3%s%U%j%/%HNJ$$%a%b%j9=@.!"%5%s%W%j%s%0J}K!$NC1=c2=!"%l%$%-%c%9%F%#%s%0K!$N:NMQ$JINFCD'rbC?%\%j%e!<%`%l%s%@%j%s%0@lMQJBNs7W;;5!$G$"$k!#K\O@J8$G$O8=:_F0:n$7$F$$$k *ReVolver*/C40 $N%5%V%;%C%H$rMQ$$$?@-G=I>2A$r9T$C$?7k2L$r<($7!"$=$l$KBP$9$k9M;!$r=R$Y$k!#*ReVolver*/C40 $O!"1 %U%l!<%`$r 128^2 pixel!"%\%j%e!<%`6u4V$r $128^3$ voxel!"%7%9%F%`%/%m%C%/<~GH?t$r 25MHz H7$?>l9g$N2hA|@8@.B.EY$NI>2A$r9TC?7k2L!"12.51 %U%l!<%`/IC$N@-G=$,F@ilk3H,o+C?!#

Performance Evaluation of Parallel Volume Rendering Machine *ReVolver*/C40

Naoki Yoshitani,[†] Daisuke Shigeta,[††] Masahito Goshima,[††]
Shin-ichiro Mori[††] and Shinji Tomita[††]

ReVolver/C40 is a parallel machine designed specially for volume rendering. The features of this machine are three stages macro-pipeline structure,various kind of parallelism in each stage, conflict free volume memory, the simplification of the way to sampling and adoption of the ray-casting algorithm.This paper describes performance evaluation of *ReVolver*/C40. As a result of this performance evaluation,we find that *ReVolver*/C40 can generate images of 128^2pixels from 128^3 voxels volume in 12.51frames/s under system clock frequency of 25 MHz.

1. O8aK

%\%j%e!<%`%l%s%@%j%s%0$O!"3<!856u4V$rC10lN)J}BN(%\%/%;%k$H8F$V) $G9=@.$5lF$$$k$H9M$(!"3N6u4V$r2<!85$N%9%/%j!<%s$KEj1F$9$k5;K!$G$"$k!#3N5;K!$O!"0eNE2hA|J,Ln$K$*$1$k?MBNFbIt$N2D;k2=$d!"%9!<%Q!<%3%s%T%e!<%?$JIN9bB.$J7W;;5!$rMxMQ7?2J3X5;=Q7W;;$N7k2L$N2D;k2=Kh$k2r@O<jK!$H7F=EMW;k5l$F$$$k!#$=$N$?$a2f!9$O0eNE2hA|@8@.$@1GJ/!"2J3X5;=Q7W;;$N7k2L$N2D;k2=rb9T$($kh&$J?7$7$$@lMQJBNs7W;;5! *ReVolver*/C40 $r3+H/$9k?aK@_7W!"<BAu$r9T$CF-$?!#$=$N7k2L!"8=:_ *ReVolver*/C40 O=$N%5%V%;%C%H$,F0:n7F$$$k!#:#2s$=$N%5%V%;%C%H$rMQ$$$F *ReVolver*/C40 $N@-G=I>2A$r9TC?!#

K\9FGOBh2>OK*$$$F *ReVolver*/C40 $N35MW$K$D$$$F=R$Y!"Bh3>O$G$O *ReVolver*/C40 GNJBNs=hM}JiSK%"!<%-%F%/%A%c$NFCD'$K$D$$$F=RYk!#Bh4>OGO *ReVolver*/C40 $N%5%V%;%C%H$rMQ$$$?@-G=I>2A$r9T$$!"Bh5>O$G%7%9%F%`$N>.7?2=$K4X$9$k9M;!$r9T$&!#$=7FBh6>OG^Ha$k!#

2. *ReVolver*/**C40** $N35MW

2.1 *ReVolver*/**C40** $NFCD'

ReVolver/C40 Kh$k%\%j%e!<%`%l%s%@%j%s%0$rC#@.$9$k$?$a$K$O!"H>F)L@%\%j%e!<%`$NI=<(!"1s6aK!Kh$k2hA|@8@.!"9bB.IA2h$H$$$&3DNMW7o$rK~B-$9kI,MW,$"$j!"$=$l$>$lKBP7$F0J2<$K<($9%"%W%m!<%A$rHC$?!#

H>F)L@%\%j%e!<%`$NI=<( 2J3X5;=Q7W;;$N2D;k2=$KMxMQ$9$k$?$a$K!"*ReVolver*/C40 $O%\%j%e!<%`$rH>F)L@$JJ*BNH7$FI07$&3H$G!"%\%j%e!<%`A4BN$NMM;R$rGD0.$9k3Hr2DG=K7$?!#

[†] 5~ETBg3XBg3X1!9)3X8&5f2J>pJs9)3X@l96
Division of Information Science, Graduate School of Engineering, Kyoto University

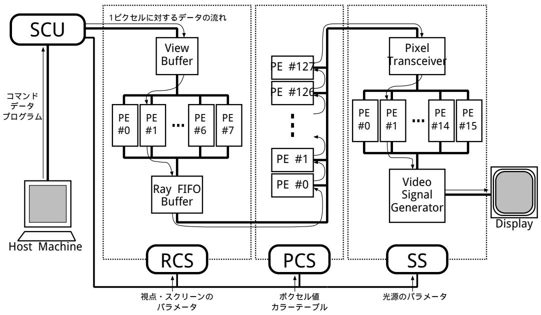
[††] 5~ETBg3XBg3X1!>pJs3X8&5f2JDL?.>pJs%7%9%F%`@l96
Division of Communications and Computer Engineering, Graduate School of Infomatics, kyoto University

1s6aK!Kh$k2hA|@8@. ;kE@$N0LCV$d;k@~$NJ}8~$K@)8B$,J/!"1s6aK!Kh$k1|9T$-N"$k2hA|I=<($r2DG=K7$?!#

9bB.IA2h %\%j%e!<%`%l%s%@%j%s%0$OKDBg$J5-21MFNL$H7W;;NL$,I,MW$G$"$k!#$3$N:]!":G$b7W;;~4V$rMW$9$k%T%/%;%kCM7W;;$r:GBg8BJBNs2=$9$k$3$H$rG0F,$K$*$$$?!#$=$N$?$a$K!"1) %1%$%-%c%9%F%#%s%0%"%k%4%j%:%`$r:NMQ$7!"2) <g<4Ey4V3V%5%s%W%j%s%0%"%k%4%j%:%`[1]$K4p$E$$$?!"3) %P%s%/%3%s%U%j%/%HNJ$$3<!85%a%b%j$r3+H/$7$?!#

2.2 *ReVolver*/**C40** $N9=@.

%\%j%e!<%`%l%s%@%j%s%0=hM}$O!"Bg$-$/$o$1$F;k@~@8@.!"%T%/%;%kCM7W;;!"%7%'!<%G%#%s%0$N3$D$N=hM}$K$o$1$i$l$k!#*ReVolver*/C40 $G$O$3$l$i$N3$D$N=hM}$KFC2=$7$?4pHD$r@_7W!"<BAu$7!"$=$l$i$r@\B3$9$k$3$H$G%\%j%e!<%`%l%s%@%j%s%0=hM}$r9bB.$K9T$&$3Hr9M$($?!#*ReVolver*/C40 $O?^1$K<(9h$&$J9=@.r7$F$$$k!#



?^**1** *ReVolver*/C40 $NA4BN9=@.

0J2<$K*ReVolver*/C40 $N9=@.MWAG$K$D$$$F=RYk!#

%7%9%F%`%3%s%H%m!<%k%f%K%C%H(**SCU**) %7%9%F%`A4BN$N@)8f$r9T$$!"%[%9%H%^%7%s$+$i$N;X<($K7?$,$C$F!"B>$N9=@.MWAGKBP7$F%3%^%s%I/%G!<%?$rE>Aw9k!#

;k@~@8@.%9%F!<%8(**RCS**) RCS $OSCU $+$i;kE@$H%9%/%j!<%s$K4X9k%Q%i%a!<%?(%S%e!<%G!<%?)$r<u$1<h$j!"$3li$N%G!<%?$H3F%T%/%;%k$N%9%/%j!<%s:BI8$+$i;k@~%Y%/%H%k$r5a$a!"PCS K*1k%\%/%;%k%5%s%W%j%s%05Z$SSS K*1k%7%'!<%G%#%s%0KI,MWJ%G!<%?(;k@~%G!<%?)$r=PNO$9$k!#RCS K*1k3liN=hM}$rAm>N7F;k@~@8@.=hM}$H8F$V!#

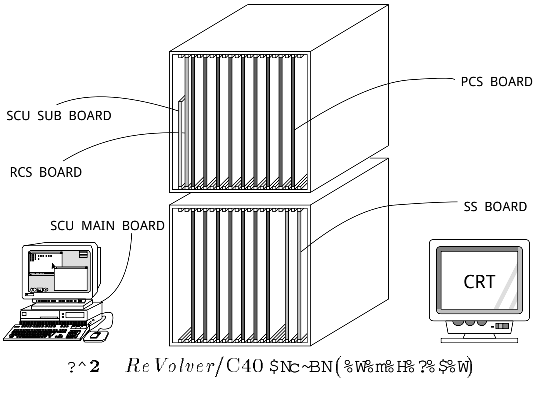
%T%/%;%kCM7W;;%9%F!<%8(**PCS**) PCS $O%\%j%e!<%`%G!<%?$rJ];}7F$$$k%9%F!<%8G"$j!"RCS $+$i$N;k@~%G!<%?$r<u$1<h$j!"3liN%G!<%?$K4p$E$$$F$=$N;k@~>eK"$k%\%/%;%kCM$rFI$_=P$9!#%\%/%;%kCM$O1byte $N%$%s%G%C%/%9CMJN$G!"$3lrMQ$$$FB0@-%F!<%V%k[1]$r;2>H$7!"%\%/%;%k$N?'$dF)L@EY$r5a$a$F%T%/%;%kCM7W;;$r9T$&!#$=7F$=$N%T%/%;%kCM$rSS XAwk!#

%7%'!<%G%#%s%0%9%F!<%8(**SS**) SS $O!"PCS $+$iAwilF/$k%T%/%;%kCM$r!";k@~%G!<%?$K4p$E$-E,@Z$J=g=xKJBSBX$(!"1%U%l!<%`J,$N%G!<%?$,B7$C$?CJ3,$G%7%'!<%G%#%s%0$r9T$$!"$=$N7k2L$rCRT$K=PNO9k!#

3F4pHDKOProcessing Element(PE)H7$F!"TI<R$NDSP G"$kTMS320C40 $r;HMQ$7$F$$$k!#SCU $r=|$/3F4pHDKO!"$=$l$>$l8 8D$NPE $,Ek:\$5lF$$$k!#*ReVolver*/C40 $r9=@.$9k?aK$O!"3F%9%F!<%8$N4pHDO=l>$l<!$Nh&$JKg?t$,I,MWG"$k(I=1;2>H)!#$3li$N4pHD$OSCU $N0lIt$r=|$$$FVME $N%H%j%W%k%O%$%H%5%$%:$Nc~BN2 DK<}G<5l$k!#%W%m%H%?%$%W%7%9%F%`$Nc~BN$NMM;R$r?^2$K<($9!#$3$Nc~BN$NCfKO%P%C%/%W%l!<%s$,<h$jD1ilF*$j!"3F%9%F!<%8$O0lIt$r=|$$$F%P%C%/%W%l!<%sKh$j@\B3$5lk!#B>Kb%P%C%/%W%l!<%s$O!"*ReVolver*/C40 $KEE8;$d%/%m%C%/?.9f!"$=$7$F%j%;%C%H?.9f$r6!5k9kLr3dbO$?$7$F$$$k!#SCU $NCf?4ItJ,$O%[%9%H%^%7%s$NPCI %9%m%C%H$KA^F~5l!"*ReVolver*/C40 $N3F%9%F!<%8$H$NDL?.$K$O%U%i%C%H%1!<%V%k$rMQ$$$k!#

I=**1** *ReVolver*/C40 $N9=@.$N$?$aKI,MWJ3F4pHD$NKg?t

4pHDL>	4pHDKg?t	
	:G=*9=@.	%W%m%H%?%$%W
SCU	1 Kg	1 Kg
RCS	1 Kg(PE8 Bf)	1 Kg(PE8 Bf)
PCS	64 Kg(PE512 Bf)	16 Kg(PE128 Bf)
SS	2 Kg(PE16 Bf)	2 Kg(PE16 Bf)



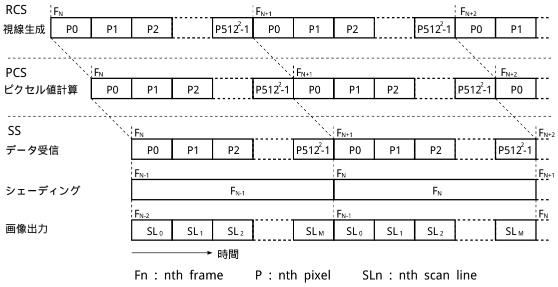
?^**2** *ReVolver*/C40 $Nc~BN(%W%m%H%?%$%W)

3. *ReVolver*/**C40** GNJBNs=hM}JiSK%"!<%-%F%/%A%c$NFCD'

3.1 *ReVolver*/**C40** GNJBNs=hM}

%\%j%e!<%`%l%s%@%j%s%0=hM}$OB?Bg$J7W;;NL$,I,MW$G$"$k$?$a!"JBNs=hM}$,IT2D7g$G$"$k!#3N$?$a*Re*-

Volver/C40 GOMM!9$J5,LO!"7A$NJBNs=hM}$r9T$C$F$$$k!#$^$:*ReVolver*/C40 $O!"%U%l!<%`C10L$G2hA|@8@.!y!"%7%'!<%G%#%s%0!"2hA|=PNO$rFHN)$K=hM}9k3HKhCF%^%/%m%Q%$%W%i%$%s$r7A@.$7!"9bB.$JI=<($r2DG=H7$F$$$k!#5i$K!"2hA|@8@.$K$*$$$F$O%T%/%;%kC10L$N%Q%$%W%i%$%s=hM}$,9T$olF$$$k(?^3;2>H)!#



?^**3** *ReVolver*/C40 $N%Q%$%W%i%$%s9=@.

$^$?!"3F%9%F!<%8Gb0J2<$K<($9h&$JMM!9$JJBNs=hM}$r9T$C$F$$$k!#

RCS GNJBNs=hM} PCS $NB.EY$K8+9gC?B.EY$G;k@~%G!<%?$r@8@.9k$?$a!"8Bf$NPE $G%U%l!<%`$r%9%-%c%s%i%$%sC10L$N%5%$%/%j%C%/$KJ,3d$7!"@EE*Ii2YJ,;6$9k3HKhC$F!"JBNs=hM}$r9TCF$$$k!#NY@\$9$k%9%-%c%s%i%$%sFbGOIi2Y$N5^JQ$,>.$5$$$?$a!"PE 4V$NIi2YNJPj$b>/$J$$!#$^$?!"RCS $N3FPE $GJBNs$K@8@.5l$?;k@~%G!<%?$O!"PCS $KE>Aw$9$k:]$K%7%j%"%i%$%:$5lk!#$=$N:]PCS GN=hM}NCYlKHbJ$$&DL?.CY1d$r5[<}$9k?aK!"FIFO %a%b%j(Ray FIFO Buffer)$rPCS $HRCS $N3FPE $N4V$KEk:\$9k3HK7?!#$^$?3FPE $ND4Dd$Khk%*!<%P%X%C%I$r8:>/$5$;$k$?$a!"1EY$KJ#?t(64words)$N;k@~%G!<%?$rE>Aw$9k3HK7?!#

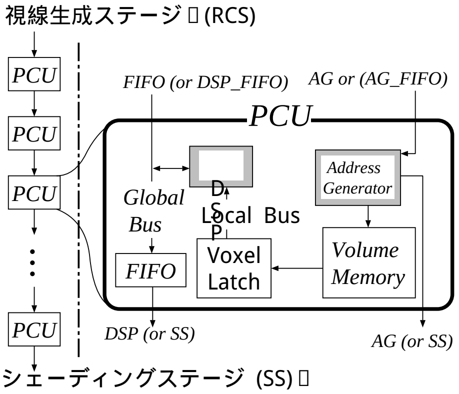
PCS GNJBNs=hM} PCS $O%Q%$%W%i%$%s9=@.$KJCF*$j!"$=l>lNPE $O;kE@$K6a$$%\%/%;%k$+$i=g$K%T%/%;%kCM$r7W;;$7!"<+J,$N=hM}$,=*$okH<!$NPE $K7W;;7k2L$rEO$9!#%W%m%H%?%$%WGOPE $r128Bf;HMQ$9$k!#

SS GNJBNs=hM} SS GO!"1)PCS $+$iC`<!E*KAwilF$/$k%G!<%?$N<u<h$jH=lr16Bf$NPE $G=hM}$9k?aNJ,G[!"2)%7%'!<%G%#%s%0!"3)%7%'!<%G%#%s%0$5$l$?%G!<%?$N<}=8$H2hA|=PNO!"$H$$$&3CJ$N%Q%$%W%i%$%s=hM}$r9TCF$$$k!#1)$H3)$KBP7F$O@lMQ%O!<%I%&%'%"($=l>lPT*hSVSG)$r@_$1F*$j!"%Q%$%W%i%$%s=hM}$HJBNs=hM}$=$l$>$lGN%G!<%?<x<uJ}K!$N:90[$r5[<}7F$$$k!#$^$?%9%/%j!<%s$r16 8D$NNN0h$KJ,3d$7!"$=$l$>$l$r0l$D$NPE $K3d$jEv$F!"%7%'!<%G%#%s%0=hM}$rJBNs$K9T$&!#

>e=RNDLj RCS $HSS $O!"=hM}$9Y-%G!<%?KBP7$F!"6u4VE*$JJBNs=hM}$r!"$^$?PCS $O!";~4VE*$JJBNs=hM}r=l>$l9T$C$F$$$k!#3Nh&$K RCS $HPCS!"PCS $HSS HN4VGO!"JBNs=hM}$N7ABV$,0[Jk$?$a!"RCS JiSKSS GO!"JBNs=hM}8zN($rDc2<$5$;$:K3li$N:90[$r5[<}9k$?$a$NA<CV$,9V8ilF$$$k!#

3.2 PCS $N%a%b%j%"%/%;%95!9=$NFCD'

PCS $O?^4$Nh&$K%T%/%;%kCM7W;;%f%K%C%H(PCU)$r1<!85$K@\B3$5$;$?9=@.$HJC$F$$$k!#3NPCU $G!"$"$k%9%i%$%9!y!y$N%\%/%;%kCM$r4pK=$N%9%i%$%9$^$G$N%T%/%;%kCM$r5aak!#%\%/%;%kCM$r3JG<$9$k3D Volume Memory H7$F;HMQ9kDRAM $O!"%"%/%;%9;~4V$,Hf3SE*Bg$-$/!"%T%/%;%kCM7W;;;~4V$HHf3S$7$FL5;k$G$-$J$$!#7+$7!"FI$_=P$9%\%/%;%kCM$N%"%I%l%9$O;k@~%G!<%?$N$_$+$i5a$ailk3HKCeL\$7!"%5%s%W%j%s%0$9$k%\%/%;%kCM$N%"%I%l%97W;;$HFI$_=P$7$r9T$&@lMQ%O!<%I%&%'%"(AG)$r@_$1$F!"%\%/%;%kCM$N%W%j%m!<%I$r9T$&!#3N$?$a$KPCU 4V$G$OAG $G07$&%G!<%?$rAG bus!"DSP $G07$&%G!<%?$rDSP bus $H$$$&2 7OE}$N%G!<%?%Q%9$Ko1$FDL?.$r9TCF$$$k!#3lKh$j!"%a%b%j%"%/%;%9$H%T%/%;%kCM7W;;$NJBNs<B9T$,2DG=HJ$j!"%\%/%;%kCM$NFI$_=P$7;~4V$N1#JC$r?^CF$$$k!#



?^**4** PCU $N9=@.?^

4. *ReVolver*/**C40** $N@-G=I>2A

$3$3GO<g$K *ReVolver*/C40 $N2hA|@8@.B.EY$K$D$$$F$NI>2A$r9TJ&!#3.1@a$G=R$Y$?$h$&$K!"*ReVolver*/C40 $O!"%U%l!<%`C10L$G%^%/%m%Q%$%W%i%$%s$r7A@.$7$F$$$k!#$h$C$F!"*ReVolver*/C40 $N2hLL@8@.B.EY$O1%U%l!<%`$K$+$+$k=hM};~4V$,0lHVBg$-$JItJ,

---

!y *ReVolver*/C40 GN2hA|@8@.$O;k@~@8@.!"%T%/%;%kCM7W;;!"SS GN%G!<%?<u?.$N3 DN=hM}$r$$$&!#

!y!y %\%j%e!<%`6u4Vr"$k<4$KBP7F?bD>$KEyJ,3d$7$?ItJ,6u4V!#

$KN'B.$5lk!#

4.1 *ReVolver*/C40 $N%W%m%H%?%$%W$N%5%V%;%C%H$rMQ$$$?@-G=B,Dj7k2L

$^$:*ReVolver*/C40 $N%W%m%H%?%$%W$N%5%V%;%C%H$rMQ$$$F$N2hLL@8@.;~4V$rB,Dj9k!#3N%5%V%;%C%H$O3F4pHD$NPE $,RCS3 Bf!"PCS8 Bf!"SS8 Bf$H$$$&9=@.HJCF$$$k!#hC$F=hM}2DG=$J:GBg%\%j%e!<%`6u4V$OPCS $NPCU $,4 J?LL=hM}$7$?>l9g$N 32^3 voxel[!y] G"$k!#

ReVolver/C40 $N%5%V%;%C%H$rMQ$$$?2hLL@8@.B.EY$rI=2$K<($9!#

I=**2** *ReVolver*/C40 $N2hLL@8@.B.EY(<BB,)

1PCU C4Ev %9%i%$%9?t	2hLL%5%$%: (pixel)	1 2hLL=hM} ;~4V(ms)	2hLL@8@.B.EY (frames/s)
1 %9%i%$%9	128^2	79.94	12.51
2 %9%i%$%9	128^2	93.58	10.68
4 %9%i%$%9	128^2	135.82	7.36

<!$K%5%V%;%C%H$N3F%9%F!<%8$N<BB,$r<($9!#I=3 $KRCS $N<BB,!"I=4$K2hLL%5%$%:$128^2$pixel GNPCS $N<BB,$+$i5a$a$?1 %T%/%;%k$N=hM}KMW9$k;~4V!"I=5$KSS $N<BB,$r<($9!#

I=**3** RCS $N2hLL@8@.B.EY(3 Bf$G$N<BB,)

2hLL%5%$%: (pixel)	1 2hLL=hM};~4V (ms)	2hLL@8@.B.EY (frames/s)
128^2	75.9	13.18
256^2	308.6	3.24
512^2	1206.2	0.83

I=**4** PCS $N2hLL@8@.B.EY$H1 %T%/%;%k$N=hM}$KMW9k;~4V(8 BfGN<BB,)

1PCU C4Ev %9%i%$%9?t	1 2hLL=hM} ;~4V(ms)	2hLL@8@.B.EY (frames/s)	1 %T%/%;%k =hM};~4V(μs)
1 %9%i%$%9	79.94	12.51	4.88
2 %9%i%$%9	93.58	10.68	5.71
4 %9%i%$%9	135.82	7.36	8.29

I=**5** SS $N2hLL@8@.B.EY(8 Bf$G$N<BB,)

2hLL%5%$%: (pixel)	1 2hLL=hM};~4V (ms)	2hLL@8@.B.EY (frames/s)
128 × 64	20.41	41.00
256 × 128	80.93	12.36
512 × 256	323.26	3.09

ReVolver/C40 $N%f!<%6$KHCFO!"2hLL@8@.B.EY$b=EMW$G$"$k$,!"<B:]$K;HMQ9kH-$N;H$$$d$9$5$b=EMW$G$"$k!#*ReVolver*/C40 $G%f!<%6%$%s%?%U%'!<%9$rC4$C$F$$$kNOSCU G"$k!#0J2<$G$O%f!<%6$+iNMW5aK3$?$(k?aNSCU $N=hM}$N<BB,$r<($9!#

%S%e!<%G!<%?$NE>Aw(JQ99) *ReVolver*/C40 GO;kE@$NJQ99$r%j%"%k%?%$%`$K9T$J$&$?$a$K!"%S%e!<%G!<%?(12word)$rE>Aw$9$k!#$3$NE>Aw;~4V$r<BB,$7$?$H$3$m!":GB.$G4.32$\mu$s $G1 2s$NE>Aw$r=*$($k!#%S%e!<%G!<%?$NJQ99$O1 %U%l!<%`C10L$G9Tolk,!"1 %U%l!<%`J,$N=hM};~4V$KBP$7$F==J,C;$$$?$a*ReVolver*/C40 $N2hLL@8@.B.EY$K1F6A$rM?$($k$3$H$O$J$$!#$9$J$o$A!"%f!<%6$+$i$N;kE@JQ99;X<($K%j%"%k%?%$%`$GDI=>$G$-$k3H$,$o$+$C$?!#

%\%j%e!<%`%G!<%?$NE>Aw(JQ99) *ReVolver*/C40 $G$O:G=i$K%\%j%e!<%`%G!<%?$rDRAM $K3JG<$9kI,MW,$"$k!#$^$?!"ESCf$G%\%j%e!<%`%G!<%?$rJQ99$7$?$$$H$$$&MW5a$b$G$F$/$k$G$"$m$&!#$3$NE>Aw;~4V$r<BB,$7$?$H$3$m!"$32^3$voxel J,$N%G!<%?(96KByte)$NE>Aw$KLs82ms MW$7$?!#$3$l$h$j$512^3$voxel $N>l9g$G$bLs7 J,$GE>Aw$,=*N;$9$k$3$H$,$o$+$k!#B?$/$N>l9g%f!<%6$O0lEY%\%j%e!<%`%G!<%?$rAwkH!"7Pi/O=$N%G!<%?$G;kE@rJQ(J,$i4Q;!$r9T$&$N$G!"IQHK$K%\%j%e!<%`%G!<%?$rJQ99$9k3HO$J$$$H;Wol$k!#$=$NE@$G$O==J,%f!<%6$NMW5aK3$?$(il$k!#

4.2 *ReVolver*/C40 $N%W%m%H%?%$%W$N@-G=M=B,

$3$3GO4.1@a$N7k2L$r4pK7$?*ReVolver*/C40 $N%W%m%H%?%$%W(I=1;2>H)$N2hLL@8@.B.EY$N@-G=M=B,$r9T$&!#M=B,$N7k2L!"RCS $N2hLL@8@.B.EY$O!";k@~@8@.=hM}$H;k@~%G!<%?E>Aw$NIAi+$KN'B.$5lk$,!"$9YF$N2hLL%5%$%:$G;k@~@8@.=hM}$,RCS $N2hLL@8@.B.EY$r7hDj9k3H$,$o$+$C$?!#$^$?SS GOPT GN%T%/%;%kCM<u?.=hM}$,SS $N2hLL@8@.B.EY$r7hDj9kBg$-$JMW0xG"k3H,o+C?!#I=6$K*ReVolver*/C40 $N%W%m%H%?%$%W$N@-G=M=B,$r<($9!#

I=**6** *ReVolver*/C40 $N%W%m%H%?%$%W$N@-G=M=B,

2hLL%5%$%:(pixel)	2hLL@8@.B.EY(frames/s)		
	RCS	PCS	SS
128^2	35.14	12.51(1 %9%i%$%9)	24.50
		10.68(2 %9%i%$%9)	
		7.36(4 %9%i%$%9)	
256^2	8.64	2.67(2 %9%i%$%9)	6.18
		1.84(4 %9%i%$%9)	
512^2	2.21	0.46(4 %9%i%$%9)	1.55

PCS Ms$N3g8IFb$O1PCU C4Ev%9%i%$%9?t!#

3N7k2L!"*ReVolver*/C40 $N%W%m%H%?%$%WGO%5%V%;%C%H$N>l9g$HF1$8$h$&$K!"PCS $N2hLL@8@.B.EY$,

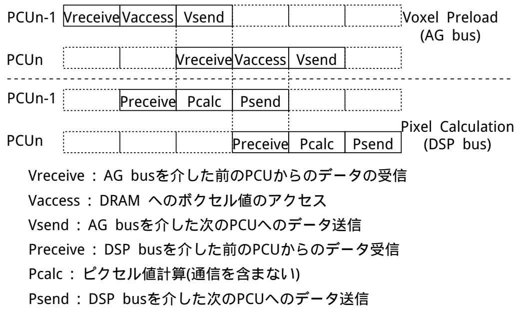
---

[!y] %\%j%e!<%`6u4V%5%$%:=(PCU Bf?t×C4EvJ?LL?t)^3

ReVolver/C40 $NB.EY$r7hDj9k3H$,$o$+$C$?!#0J2<$G$O*ReVolver*/C40 $rN'B.$9$kPCS $N=hM}$K4X9kI>2A$r=R$Y$k!#

4.3 PCS $NI>2A

PCS $N2hLL@8@.B.EY$O!"?^5$K<($9h&$K!"3FPCU GN%T%/%;%kCM7W;;~4V$HAG $,%\%/%;%kCM$rFI$_=P$9;~4VNIAi$+$K0MB8$9$k!#$=$3$G!"$=l>lN1;k@~J,$N=hM}$KMW9k;~4V$rFHN)$KB,Dj7?;~4V$rI=7$K<($9!#[!y]



?^**5**　%T%/%;%kCM7W;;$H%W%j%m!<%I$N%Q%$%W%i%$%s$NMM;R

I=**7**　1%T%/%;%k$N=hM}$KMW9k;~4V

1PCU C4Ev%9%i%$%9?t	%T%/%;%kCM7W;;~4V(μs)	%W%j%m!<%I;~4V(μs)
1 %9%i%$%9	3.28	2.52
2 %9%i%$%9	4.80	2.80
4 %9%i%$%9	7.24	3.36

4.3.1 AG $N8z2L$K4X9kI>2A

?^5$HI=7$+$i9MN8$9kH!"%T%/%;%kCM7W;;~4V$,PCS $NB.EY$r7hDj$7!"%\%/%;%kCM$N%W%j%m!<%I$N;~4V$O1#JCG-kH?dB,G-$k!#$7$+$7I=4 NCMO!"I=7$N%T%/%;%kCM7W;;~4V$NCMhjbBg-$$!#FC$K1PCU $NC4Ev%9%i%$%9?t$,>/$J$$$[$I@-G=Dc2<$NHfN($,Bg$-$$!#3N860x$rD4$Y$?7k2L!"4pHD4V(RCS-PCS 4V!"PCS 4pHD4V!"PCS-SS 4V)$NDL?.!"FC$K$=$NCfGbAG bus $NDL?.$GAw<u?.$N;~4V$,D9$/$J$k8=>]$,4QB,5l$?!#D4::$N7k2L!"?^5GNA0CJ$NPCU $NVaccess $,=*N;$;$:!"$=$N<!$NPCU $NVreceive $NA0$KBTA,@8$8!"CY1d$,8eCJ$KEAHB$7$F$$$k3H$,$o$+$C$?!#$3lO4pHDFb$NDL?.5wN%$K$/$iYF!"4pHD4V$NDL?.5wN%$,D9$/DL?.;~4V$,Bg$-$$$3HK5/0x9k!#3l$KBP=h$9$kJ}K!$H7F!"%W%j%m!<%I$r%Q%$%W%i%$%s2=$7DL?.=hM};~4V$r1#JC$9k3H,9M$($ilk!#

8=:_$O>e=R$7$?$h$&$K!"AG 4V$N4pHD4VDL?.$GCY1d$,H/@8$7$F$$$k$,!"$b$7AG $r<BAu$7J+C?>l9g!"%T%/%;%kCM7W;;~4VOBg-$/$JkH9M$($ilk!#$=$3$GAG $N8z2L$rCNk?aK!"AG $r;HMQ$7$J$$>l9g$N%T%/%;%kCM7W;;~4V$r7WB,7?!#I=8K=$N7k2L$r<($9!#

I=**8**　%T%/%;%kCM7W;=hM};~4V$NHf3S

1PCU C4Ev%9%i%$%9?t	%T%/%;%kCM7W;;~4V(μs)	
	AG $"$j	AG J7
1 %9%i%$%9	4.88	8.31
2 %9%i%$%9	5.71	11.96
4 %9%i%$%9	8.29	19.11

3lhj!"AG $r@_$1k3HGLs1.7 G\!A2.3 G\$N=hM};~4V8~>e$,F@$ilk3H$,$o$+$C$?!#

4.3.2 %T%/%;%kCM7W;$K4X$9$kI>2A

%\%/%;%kCM$N%W%j%m!<%I$,40A4$K1#JC$G$-$?>l9g!"PCS $N2hLL@8@.B.EY$O%T%/%;%kCM7W;=hM}KhCF7hDj9k!#$=$3$G%T%/%;%kCM7W;=hM}$K$D$$$F5i$K>\$7$/I>2A$r9T$&$3HK9k!#3N=hM}$O:Y$+$/$o1k$H!"A0CJ$NPE $+$i$N%G!<%?<u?.!"%\%/%;%kCM$rMQ$$$?%T%/%;%kCM$N7W;;(DL?.$r=|$/)!"8eCJ$NPE XN%G!<%?Aw?.$H$$$&3 DN=hM}Ko1ilk!#$3$3$G%G!<%?Aw<u?.$N;~4V$r7WB,$7$?7k2L!"A0CJ$NPE $+$i$N%G!<%?<u?.$K$O1.20μs!"8eCJ$NPE XN%G!<%?Aw?.KO1.00μs G"k3H,o+C?!#D^$j%T%/%;%kCM7W;;$NCf$G!"2.20μs $ODL?.$KMxMQ5l$F$$$k$H$$$&3HKJ$k!#$3l,%T%/%;%kCM7W;=hM}NCfGINDxEY$N3d9g$r@jak$+$rI=9K7a9!#

I=**9**　%T%/%;%kCM7W;=hM};~4VNCfNDL?.;~4V$N3d9g

1PE C4Ev%9%i%$%9?t	DL?.;~4V$N3d9g
1 %9%i%$%9	67.1%
2 %9%i%$%9	45.8%
4 %9%i%$%9	30.4%

3N7k2L!"%G!<%?Aw<u?.$N;~4V$,%T%/%;%kCM7W;;~4VNCfG$+$JjN3d9g$r@j$a$F$$$k3H$,$o$+$j!"FC$K1PE $G=hM}$9$k%9%i%$%9?t$,>/$J$/$JlPJk$[$I$=$N3d9g$,Bg$-$/$Jk3H,o+C?!#D^j3$NItJ,$r2~NI9l$P*ReVolver*/C40 $N2hLL@8@.B.EY$O8~>e9k3HKJ$k!#8=:_PE 4VDL?.$K$OFIFO %a%b%j$r;HMQ$7!"%O%s%I%7%'!<%/$r9T$&$3HGFIFO %a%b%jXNAw<u?.$r9T$C$F$$$k!#3l$r1%T%/%;%kJ,$N%G!<%?$rO"B3$7$F<u$1<h$k2~NI$r9T$&$3HKhC$F!"PE 4VAw<u?.$O:GC;$G0.80μs $G9T$(kh$&$KJk!#3N>l9g%T%/%;%kCM7W;;~4V$OLs1.75 G\$NB.EY8~>eHJ$k!#

5. %7%9%F%`$N>.7?2=$K4X9k9M;!

ReVolver/C40 $G;HMQ$7$F$$$k DSP!"Memory!"FPGA Ey$NMWAG%G%P%$%9$O!"6aG/$GOh$j9b@-G=2=$+$D>.7?2=$,?^il$F$$$k!#3l$i:G6a$NMWAG%G%P%$

[!y] %W%j%m!<%I;~4V$K4X$7FO%\!<%IFbGN;~4VG"$k!#

%9$rMQ$$$?*ReVolver*/C40 $N@-G=$r0]; }7D$D>.7?2= 9kJ}K!$r9M;!9k!#

%W%m%;%C%5 8=:_$OTMS320C40 H/iY$F10 G\0J >e$N@-G=$r; }G?%W%m%;%C%5$,EP>l7F$*$j!"$3 li$r:NMQ$9lP!"PCS GN%T%/%;%kCM7W;;; ~4V $r==J,>.$5$/$9k3H,G-$k!#$7$+$7J,$i!" 1PE $"$?jN%a%b%j%P%s%II}(%i%s%@% `%"%/%;%9 ;~) $NITB-$N$?$a!"9bB.$JHFMQ%W%m%;%C%5$rMQ$$ $?>.7?2=$O:FqG$"$k!#$?$@$7!";k3Q$r@)8B9k EyKh$j%a%b%j%"%/%;%9$N6I=j@-$r>e$2!"BgMFNL %-%c%C%7%e$rJ;MQ$9k3HG9bB.2=/>.7?2=$,?^$l $k2DG=@-$,;DCF$$$k!#

%a%b%j 8=:_GOMENIE*KO!"512^3 voxel J,$N%\%/%;%k %G!<%?$r3JG<G-$kVolume Memory $,DIMM1 Kg$G9=@.2DG=G"k,!"A0=R$N%W%m%;%C%5$HF1MM $K%i%s%@% `%"%/%;%9$K4X7F$O!"*ReVolver*/C40 $N3+H/Ce<jEv;~$H$/$iYF$b?tG\DxEY$NB.EY8~>e G"$j!"*ReVolver*/C40 H7FI,MWH5l$k%a%b %j%"%/%;%9%P%s%II}$r1 Kg$NDIMM $G<B8=$9$k 3H$OIT2DG=G"$j!"=>MhDLjN%P%s/9=@.$,I, MWG"$k!#$?$@$7!"%a%b%j%"%/%;%9$N%Q%$%W%i%$ %s2=$,2DG=$G$"$kNG!"%\%/%;%kCM$N%W%j%m!<%I KI,MWJ%"%I%l%97W;;$r4^$a$?%Q%$%W%i%$%s2=$K hkB.EY8~>e$O4|BT$G$-$k!#

FPGA :G?7$NFPGA $O!":GBg%2!<%H?t500000 %2!< %H!":GBg%f!<%6;HMQ2DG=%T%s?t448 K\!":GB.%/%m%C %/<~GH?t200MHz $N@-G=$r; }CF$*$j!"FC$K%2!< %H?t$K4X7F$OHtLvE*$J8~>eG"$k!# *ReVolver*/C40 $G;HMQ$7$F$$$kFPGA(XC4010D) $O!"$=$N%2!<%H?t$H%f!<%6;HMQ2DG=%T%s?t$K@)8B 5lk?$a!"8=:_$O%\%/%;%kCM$N%W%j%m!<%I$K@l G0$7$F$$$k!#7+$7PCS GN%T%/%;%kCM7W;;$O!" 4pK\E*KO2C;;4o$H>h;;4o$,$"lP<B8=2DG=G" kN$G!"FPGA $G<BAu$G$-$k!#hC$FFPGA $, %T%/%;%kCM7W;;$H%\%/%;%kCM$N%W%j%m!<%I$NN>J} $N=hM}$N%Q%$%W%i%$%s2=KI,MWJ%2!<%H?t$r; }$C $F$$$l$P!"PE $HAG $N=hM}$rFPGA C1FH$G<BAu 9k3H$,2DG=$H;Wol$k!#2C$(F3$N>19g%2!< %H?t$KM>M5$,$"lP!"A0=R$N%a%b%j%"%/%;%9$N%Q %$%W%i%$%s2=$rFPGA $G9T$&3H$,$G$-$k!#hC $FFPGA $rMQ$$$k3HKh$j!"%\%/%;%kCM$N%W %j%m!<%I$r4^$a$?%T%/%;%kCM7W;;$N%Q%$%W%i%$%s 2=Kh$kB.EY8~>e$,2DG=G"kH9M$($ilk!#

6. $^ $H $a

K\O@J8GO%\%j%e!<% `%l%s%@%j%s%0@lMQJBNs7W;;5! *ReVolver*/C40 $N@-G=I>2A$r$=$N%5%V%;%C%H$rMQ$$$F 9T$$!"$=$lKBP9$k9M;!$r9TC?!#

ReVolver/C40 GOPCS $,A4BN$NB.EY$r7hDj$7$F $$$k!#$=$3$GHf3SBP>H$H7FWork Station $rMQ$$$F %T%/%;%kCM7W;;=hM}$r9T$$!"=hM};~4V$rHf3S$9$k!#%^ %7%s$O%-%c%C%7%e$r2MByte!"%a%b%j$r1GByte Ek:\ 7?Sun ULTRA2 Model 2300 $r;HMQ$7!"2CPU $N $&$A$N1 Dr;HMQ7FJ?9TE j1FKh$k%T%/%;%kCM7W;; =hM}$r9TC?!#$=$N7k2L!"2hLL%5%$%:128^2 pixel!"%\ %j%e!<% `%5%$%:$128^3$ voxel $G!"2hLL@8@.B.EY$,J?6QLs 0.83frames/s $H$$$&7k2L$,F@$il?!#F1MM$N>r7o$G *ReVolver*/C40 $O12.51frames/s $N@-G=$,$"$k!#hC $F*ReVolver*/C40 $O%3%9%H%Q%U%)!<%^%s%9$b9MN8$K$$ lF!"HFMQ$N7W;;5!$H$/$iYF$bM-MQ$JbNG"kH $$$($k!#

<U <-

%a%s%?!<!&0%i%U%#%C%/%9!&8%c%Q%s3t<02q<RKO Higher Education Program $N0l4D$H7F@=IJ$H%5!< %S%9$r$4Ds6!D:$-!"$^$?!"F|K\%F%-%5%9!&$%s%9%D%k %a%s%H3t<02q<R$N2CF#8-Fs;aKO!"DSP %f%K%P!<%7 %F%#%W%m%0%i% `$N0l4D$H$7$FDSP 3+H/4D6-$r$4Ds6! D:$$$?$3$H$K46<U$7$^$9!#$^$?!"%W%j%s%H4pHD$N:n@.$K$46(NOD:$$$?!";0@:%7%9%F% `3t<02q<R$NF#Be;a!"?9 2,;a$K46<U7^$9!#

J*K\8&5f$N0lIt$O!"J8It>J2J3X8&5fHqJd=u6b!Ol HL8&5f(B) 2]BjHV9f10480059 $*$h$S10558045!"4p HW8&5f(C) 2]BjHV9f09680334 JiSK>)Ne8&5f(A) 2]BjHV9f09780268!KKh$k!#

;2 9M J8 8%

1) UtGOM:<!!%\%j%e!<% `%l%s%@%j%s%0@lMQJBNs7W;;5!*ReVolver*/C40, JBNs=hM}%7%s%]%8%&%` JSPP '95 H/I=O@J8(1995)

2) UtGOM:<!!%\%j%e!<% `%l%s%@%j%s%0@lMQJBNs7W;;5!*ReVolver*/C40 $N%"!<%-%F%/%A%c, JBNs=hM}%7%s%]%8%&%` JSPP '94 H/I=O@J8(1994)

3) 6b 4nET!';k3P@)8B%T%/%;%kJBNs=hM}Kh$k%\%j%e!<% `!&l%s%@%j%s%08~$-$ND69bB.@lMQJBNs7W;;5!$N%"!<%-%F%/%A%c, JBNs=hM}%7%s%]%8%&%` JSPP '96 H/I=O@J8(1996)

4) 5HC+D><y!'*ReVolver*/C40 $N@_7W5Z$S<BAu, JBNs/J,;6/6(D4=hM}$K4X$9$k!2XP$N9q!Y%5%^!<!%o!<%/%7%g%C%W SWoPP 0$AI '97 H/I=O@J8(1997)

5) F#8 6 2m9(!'3,AX3J;R%\%j%e!<% `%G!<%?$N<B;~4V2D;k2=, !VO%$%Q%U%)!<%^%s%9!&3%s%T%e!<%F%#%s%0$H%"!<%-%F%/%A%c$NI>2A!W$K4X$9$kKL3$F;%o!<%/%7%g%C%W(HOKKE-98) H/I=O@J8(1998)

6) :mEg 7IG7, @>_7Dg<!, @u8 6=EIW 6&Cx!'JBNs?^7A=hM}

7) CfEh @5G7, @n9g 7E 6&Cx!'%0%i%U%#%/%9$H%^%s%^%7%s%7%9%F% `

8) Texas Instruments!'TMS320C4x User's Guide