=$;NO@J8

F0:n%l%Y%k%O!<%I%&%′%"5-=R8@8l **Evelyn**

;XF3654l IYEDbC<#65<x

5~ETBg3XBg3Xl!9)3X8&5f2J
=$;N2]Dx>pJs9)3X@l96

=.K\0l5W

J?@.10G/27n13F|

F'0:n%l%Y%k%O!<%I%&%'%"5-=R8@8l **Evelyn**

=.K\0l5W

FhMF9<35

VHDL $dVerilog-HDL $H$$$C$?5!G=%l%Y%k%O!<%I%&%'%"5-=R8@8l(5!G=%l%Y%kHDL) $,$$$h$$$h0lHL$KIa5Z$7F-$?!%$7$+$7$3$l$i5!G=%l%Y%kHDL KhCF$b!$Ev=i8@ol$?DxKO@_7W$NCj>]EY$O>e$,i:!$?$N%H%C%W%@%&%s@_7W$r2DG=$H9kKOA4$/IT==J,G"C?!%

@_7W$NCj>]EY$,>e$,$iJ+C?NO!$HDL $N=hM}7O-<g$KO@M}:GE,2=7O$NG=NO$,IO<eG"C?3Hb5k3HJ$,$i!$$3li$NHDL $N5-=RG=NO<+BN$NDc5KbBg-$J860x$,$"$C$?!%B?$/$NHDL GO!$O@M}9g@.$r6/$/0U<1$7$F$$$k3Hb"CF!$<B:]$NO@M}2sO)$H1BP1 $GBP1~$9kh$&$K7+5-=RG-$J$$$NG"$k!%

$=$N$?$a@_7W<T$O!$@_7W$N:G=i4|$+$i!$O@M}9g@.7k2L$rM=B,$7J,$i!$%G%6%$%s$,J*M}E*@)Ls$rK~$?9h$&$K@_7W5-=R$r9T$JoJ$/$FOJiJ$$!%3lGO%H%C%W%@%&%s@_7WOFsN<!KJi6krF@$:!$@_7W$N=i4|%3%9%H!$JQ99%3%9%H$,Bg$-$JIiC4$HJCF7$^$&!%

=>Mh$N5!G=%l%Y%kHDL $NLdBjE@$O!$O@M}9g@.$r6/$/0U<1$9$kM>$j!$5-=R$,<B:]$NO@M}2sO)$K4sj9$.$F$$$?H3mK$"$k:3liNHDL $O5!G=%b%8%e!<%kC10L$K%O!<%I%&%'%"$r5-=R$9$k!%$3$N5!G=%b%8%e!<%k$H$O<B:]$NO@M}2sO)$H1BP1 $KBP1~$9$kC10L$G$"$j!$J*M}E*@)Ls$d2sO)$N6&M-$N2DG=@-$^$G9MN8$7$FJ,3d5l$?C10L$G$"$k!%

5!G=%l%Y%kHDL GO%O!<%I%&%'%"r^$:5!G=%b%8%e!<%k$KJ,3d$7!$$=l>lN5!G=%b%8%e!<%k$NF0:n$N=89gH7$F%O!<%I%&%'%"A4BN$NF0:n$rI=8=$9$k!%$=N?$aF0:n5-=R$,5!G=%b%8%e!<%k$N9=@.$KBg$-$/0MB8$9$k!%

0lJ}$G!$5!G=%b%8%e!<%k9=@.$OJ*M}E*@)Ls$KBg$-$/0MB8$9$kbNG"$k!%$=N?$aO@M}9g@./:GE,2=$N7k2L$,J*M}E*@)Ls$rK~$?$;J+C?>l9gKO5!G=%b%8%e!<%k9=@.$rJQ99$7!$F0:n5-=R$+id$jD>$5J1lPJi$J$$$NG"$k!%

K\O@J8$GDs0F$9$kF0:n%l%Y%kHDL !**Evelyn**!WJi$P=>Mh$NHDL $NLdBjE@$r2r7h$7!$?$N%H%C%W%@%&%s@_7W$r<B8=9k3H$,$G$-$k!%

Evelyn GO!$%O!<%I%&%'%"$r9b$$Cj>]%l%Y%k$G5-=R$9$k!%$bAm$sCj>]EY$r>e2k3HKh$j5-=R$r4J7iK9k3HbA@CF$$k$,!$$=$l0J>e$KJ*M}E*@)Ls

$K6/$/0MB8$9$kh&$J@_7W>pJs$rG-$k8B$jF0:n5-=R$+$iGS=|9k3H$rA@$C$F$$k!%

$=$Nh&$J@_7W>pJs$O!$F0:n5-=R$K8e$+$iIU2C9k$H$$&7A$GM?$($k!%>\:Y$J@_7W>pJs$r>/$7$:$DIU2C9k3H$G@_7W5-=R$r?JaF$$/!%

8e$+$iIU2C9k@_7W>pJsN&$AF0:n$K1F6A$rM?$($J$$h$&$JbN-Nc$(P%a%b%j$N<dN'JI$N>pJs$rFC$K9g@.%G%#%l%/%F%#%V$H8F$V!%9g@.%G%#%l%/%F%#%V$OC1$K5!G=9g@.;~$N%*%W%7%g%sH7$EM?$(kNGOJ/!$8@8l;EMM$N0lItH7$F5,Dj$9$k!%9g@.%G%#%l%/%F%#%V$r8@8l$N;EMM$H7FAH$_9~$'3H$G!$5-=R$NCj>]EY$N9b5H9g@.G=NO$N%H%l!<%I%*%U$r9b$$%l%Y%k$G%P%i%s%9$5$;$k!%

Cj>]EY$N9b$$$F0:n5-=R$r%Y!<%9$K!$>\:Y$J@_7W$rIU2C$7$F$$/$H$$&%"%W%m!<%AKh$j@_7WJQ99$N%3%9%H$rM^$($k!%$9JoA3$&$9k3HGO@M}9g@./:GE,2=7O$+$i$N%U%#!<%I%P%C/$Khj@_7WJQ99rGwil?>l9gKb!$%Y!<%9$HJkF0:n5-=R$K<j$r2C($:$K!$8e$+$iIU2C$7$?>pJs$N%^%$%J!<$JJQ99$@$1$GBP=h$G$-$kh&K9kN$G"$k!%

3N%"%W%m!<%Ahj!$Cj>]E*$J@_7W5-=R$r=y!9$K>\:Y2=7F$$/$H$$&%H%C%W%@%&s@_7W$r<B8=$9k3$H,$G$-$k!%

Evelyn GO!$%O!<%I&%'%"$rF0:nC10L-9JoAF0:n<gBNH=$NF0:n$H$$&7A$G5-=R$9$k!%

1$D1$D$NF0:n$O!$J#?t%5%$/%kKEOk0lO"$NF0:n$H7F5-=R9k!%5-=RCf$N;~4V4X78$O!$JQ?t$N0MB84X78KhCFH>=g=xE*$KDj5A$9$k!%&V3$N=hM}$,;O$^k^GK!D!W$1VD$+$i!D$^GN4V$K!D!W$J$IHs>o$K=@Fp$K;~4V4X78$rI=8=G-$k!%J*M}E*@)Ls$KhCFN$_7hDj$9lP$h$$$h$&J;~4V4X78$rL5M}$K7hDj$9kI,MW,$J$$!%

;~4VJ}8~$K5-=R$5l?0lO"$N=hM}$H!$$=3K0E<(E*$K<($5l?;~4V4X78$+$i%Q%$%W%i%$%s$r<+F09g@.$9$k!%%9%F!<%86-3&$OJQ?t$N7?$rJQ$($k$@$1G4JC1$KJQ99$9k3H,G-$k!%

3Nh&$K=@Fp!$$+$D6/NO$J5-=RG=NO$r;}$DEvelyn $O%O!<%I&%'%"3+H/$rBgI}$K8zN(2=$G$-$kbN$H9M$(il$k!%$^$?$3$N=@Fp$5N?$a!$$Evelyn $rJ}<0@_7W$N8eH>$d!$@_7WA0$N@-G=$NM=HwI>2AKb9-$/MxMQ$G$-$kbN$H9M$(il$k!%

Evelyn : A Behavior-Level Hardware Description Language

Kazuhisa Funamoto

Abstract

Function-level hardware description languages (function-level HDLs) such as VHDL or Verilog-HDL have come into wide use recently. But by using them, designers can't describe designs more abstract than they were expected. In short, these function-level HDLs can't realize the true top-down design.

Certainly, one of the reasons of that problem is the incapacity of their processor – specially their optimizer. But the most important reason is the incapacity of these HDL description. With most of these HDLs, designers must describe designs in one-to-one correspond to physical logical circuits.

So, from the very early stage, designers must consider the physical constraints and describe their designs carefully. In this situation, the top-down design is of secondary importance.And the cost of both the early stage of design and changing the design are too heavy.

The problem of conventional HDLs is that, being too conscious of logic synthesis, the unit of descriptions is too near to physical logical circuits.

When designers describe their design with these function-level HDLs, at first, they must divide their design into function modules.And then they describe the behavior of each module. A set of each behavior constructs the behavior of the whole. Therefore the behavior description of the whole is strongly depend on the division of function modules.

On the other hand, the division of the function modules is strongly depend on physical constraints. Therefore if the result of logic synthesis doesn't satisfy the physical constraint, designers must re-divide their design, and re-describe the behaviors.

New behavior-level HDL **Evelyn** that I propose in this paper can solve such problems and make the top-down designing come true.

With Evelyn, designs are described very abstractly. Of course, one reason of this approach is to make descriptions brief. But more important reason is to remove detail design information which strongly depend on the physical

constraint from the description.

Detail information is given gradually by adding to the abstract description.

Some of detail information – for example, a type of memory – doesn't effect designs' behavior except their performance. Such information is especially called **synthesizer directives**. Evelyn doesn't defines synthesizer directives as synthesizer options but defines it as the part of the language specification. This approach can well balance the trade-off between the abstractness of its description and the capability of the synthesizing.

Evelyn's approach, that designer gradually add detail design information to the base abstract description, can realize the top-down design method.

With Evelyn, the designs are described in blocks of behavior modules – that is a behavior module and its behavior.

Each behavior is described as a series of action over steps. The orders of operations is defined partially by data dependency. So designers can express abstract time conception like 'before that operation' or 'between these operations'. It is not necessary to decide the order between operations which are constrained only by the physical constraint.

Evelyn processor can synthesize pipeline circuits automatically. A series of actions in the time direction and the implicit operation ordering are used in this process. Stage boundaries can be easily changed by trading variable type.

With Evelyn it is possible to design a hardware very efficiently. And because of this flexibility, Evelyn can be use in the latter half stage of the system design and in the evaluation of the performance before the development.

F0:n%l%Y%k%O!<%I%&%'%"5-=R8@8l **Evelyn**

L\<!

1 O8aK **1**

2 GX7J **2**

2.1 =>Mh$N5!G=%l%Y%kHDL $NLdBjE@ 2

2.2 M}A[E*$J%O!<%I%&%'%"@_7W%7%9%F%` 4

3 **Evelyn** @_7W$NJ}?K **6**

3.1 %H%C%W%@%&%s@_7W$N<B8=. 6

3.2 %b%8%e!<%k6-3&$NCj>]2=. 8

3.3 9g@.%G%#%l%/%F%#%V 9

3.4 %Q%$%W%i%$%s$NCj>]2= 9

3.4.1 ;~4VJ}8~$NF0:n5-=R 10

3.4.2 %Q%$%W%i%$%s$N<+F09g@. 11

3.4.3 5!G=%l%Y%kHDL $HHf3S$7$F 12

4 **Evelyn** $N35G0 **15**

4.1 %b%8%e!<%k6-3&$NCj>]2=. 15

4.1.1 %b%8%e!<%k$H%U%!%s%/%7%g%s 15

4.1.2 %U%!%s%/%7%g%s 15

4.1.3 @)Ls%U%!%s%/%7%g%s 16

4.1.4 %U%!%s%/%7%g%s8F$S=P$7$N%;%^%s%F%#%/%9 17

4.1.5 %$%K%7%c%k!&%U%!%s%/%7%g%s 17

4.2 %U%!%s%/%7%g%s$NF0:n 17

4.2.1 singal $Hsignal 17

4.2.2 %U%!%s%/%7%g%sFbIt$NF0:n%b%G%k. 19

5 F0:n5-=R **20**

5.1 %b%8%e!<%kIt. 20

5.2 %U%!%s%/%7%g%s 21

5.2.1 %U%!%s%/%7%g%s 21

5.2.2 %U%!%s%/%7%g%s$NG[Ns. 22

5.2.3 @)Ls%U%!%s%/%7%g%s 22

5.3 30It%b%8%e!<%kHNDL?. 24
5.4 singal 25
5.4.1 F14|J}K!$N;XDj 25
5.4.2 %a%b%j$N5-=R 28
5.5 5-=RNc 28
5.6 F0:n5-=RN^Ha. 32

6 5!G=9g@. 33

6.1 5!G=9g@.$N35MW 33
6.1.1 5!G=9g@.7O. 33
6.1.2 9g@.%G%#%l%/%F%#%V 33
6.2 %b%8%e!<%k$N5!G=9g@. 35
6.2.1 %U%!%s%/%7%g%s$N%(%s%3!<%G%#%s%0 35
6.2.2 ;q8;6&M- 36
6.2.3 5!G=%b%8%e!<%kXN%^%C%T%s%0 36
6.3 %U%!%s%/%7%g%s$N5!G=9g@. 37
6.3.1 %9%F!<%8J,3d<jK! 37
6.4 singal $N9g@. 41
6.4.1 J}?K 42
6.4.2 %/%m%C%/$N5,Dj 42
6.4.3 5-21AG;R$N;XDj 42

7 F0:n%7%_%e%l!<%7%g%s 43

7.1 F0:n%7%_%e%l!<%?$,Ds6!$9$k5!9= 43
7.1.1 %F%9%H%Y%s%A$N5-=R 43
7.1.2 ;~AjO@M}<05-=R$N%5%]!<%H 44
7.2 Evelyn $NF0:n%b%G%k 44
7.3 %7%_%e%l!<%7%g%s<jK! 45
7.3.1 @)Ls%U%!%s%/%7%g%s$N<B9T=g=x 45
7.3.2 <B9T%9%1%8%e!<%j%s%0. 46

8 $*$ojK 46

<UK- 48

1 O8aK

VHDL $dVerilog-HDL $H$$$C$?%O!<%I%&%'%"5-=R8@8l(HDL) $H!$$=li$+$i$N(H>) <+F'0E*$JO@M}9g@./O@M}:GE,2=Kh$k%O!<%I%&%'%"@_7W<jK!$,0lHL$KIa5Z$7DD$"$k!%3liNHDL Kh$k@_7W<jK!$KhC$F!$=>Mh$N2sO)?^F~NO$Khk@_7W<jK!KBP7$F!$@_7W$N8zN($O3N$+$KHtLvE*$K8~>e$7$?!%

7+$7!$$3li$NHDL KhCF$bEv=i8@$ol?Dx$K@_7W$NCj>]EY$,>e$,kH$$&3HOJ$/!$K\Ev$N0UL#$G$N%H%C%W%@%&%s@_7W$r2DG=H9kK$OA4$/IT==J,G"C?!%8@8lF~NOKO2sO)?^F~NOKHfY$FF~NO$d=$@5$,MF0WKJkH$$$&MxE@$,$"k,!$$3li$NHDL $NF3F~$KhC$FF@$il?8zN(2=O'7m3N3HKh$kItJ,$,Bg$-$$!%

@_7W$NCj>]EY$,>e$,$iJ+C?NO!$HDL $N=hM}7O-<g$KO@M}:GE,2=7O$NG=NO$,IO<eG"C?3Hb5k3HJ$,$i!$$3li$NHDL $N5-=RG=NO<+BN$NDc5KbBg-$J860x$,$"$C$?!%O@M}9g@.$r6/$/0U<1$7$F$$k3Hb"$j!$B?$/$NHDL GO<B:]$NO@M}2sO)$H1BP1 $GBP1~$9kh$&$K7+5-=RG-$J$$$NG"$k!%

$=$N$?$a!$@_7W$N:G=i4|$+$i!$2sO)$,J*M}E*@)Ls$rK~$?9h$&$K!$O@M}9g@.$5lk2sO)$rM=B,$7J,$i@_7W5-=R$r9TJoJ/FOJi$J$$!%3lGO%H%C%W%@%&%s@_7WOFsN<!KJi6krF@$:!$@_7W$N=i4|%3%9%H!$=$@5%3%9%H$,Bg$-$JIiC4HJGF7^$&!%

K\O@J8$GDs0F$9$kHDL !**Evelyn**!W$JiP3liNLdBjE@$r2r7h$7!$%H%C%W%@%&%s@_7W$r<B8=G-$k!%

3l$^$G$NHDL GOO@M}9g@.$r6/$/0U<1$9k"$^$j5!G=C10L$K5-=R$7!$$=lr%Y!<%9$KF0:n$r5-=R9k$H$$&%"%W%m!<%A$r:N$C$F$$k!%$=$lKBP7Evelyn $O!$%O!<%I%&%'%"$rF0:nC10L$K5-=R$7!$$=3K5!G=%l%Y%k$N@_7W>pJs$rIU2C9k$H$$&%"%W%m!<%A$r:N$k!%3&9l$P!$@_7W$N=i4|$K$OF0:n@_7W$N$_$K@l?4G-!$$^$?5!G=%l%Y%k@_7W9)Dx$G$NJQ99$,F0:n5-=R$K1F6A$r5Z$\$9$3$HOJ$$!%

Evelyn $NF0:n5-=R$OHs>o$K6/NO$G$"$k!%%O!<%I%&%'%"$NF0:n$r;~4VJ}8~$KAGD>$J7A$G5-=R$9k3H,G-$!$$=3+$i%Q%$%W%i%$%s$r<+F'09g@.G-$k!%$7$+$b%Q%$%W%i%$%s!&9%F!<%89=@.r[Hs$I%3%9%H$r$+$1$:$KJQ99$9$k3H$,$G$-$k!%$=$N$?$aEvelyn $O!$J}<0@_7W$N=*HW$+$iMxMQ$G$-$k2DG=@-$r;}$D!%

K\9FGO3Nh&$JFCD'$r;}$DF0:n%l%Y%kHDL Evelyn $rDs0F$9$k!%0J2<!$

$^$:2>O$G=>Mh$NHDL GO2?8N%H%C%W%@%&%s@_7W$,:$FqJN$+!$=>Mh$NHDL $NLdBjE@$rL@3NK7!$}>O$GEvelyn $,%H%C%W%@%&%s@_7W$r2DG=H9k?aNJ}?K$r=R$Y$k!%$=7F5>O$GEvelyn Kh$kF0:n5-=R$NMF0W5r=R$Y!$$5iK6>OG=$N5-=R$N5!G=9g@.<jK!!$7>O$GF0:n%7%_%e&l!<%7%g&s<jK!KD$$F@bL@9k!%

2 GX7J

Evelyn KD$$F=RYkA0$K!$$J$<=>Mh$NHDL $,%H%C%W%@%&%s@_7W$K7kSIU+J+$C?$N$+$C?N+!$K\>O$G$=$NLdBjE@$rL@$i$+$K9k!%

0J2<GO<!Nh$&$K5DO@$r?J$ak^$:2.1@a$G4{B8$NHDL $rMQ$$$?%O!<%I%&%'%"@_7WGOINh&$J;vJA$,LdBjHJCF$$k$+=R$Y$k!%$=7F$=$Nh&$JLdBj$,2?8N@8$8$kN+9M;!7?8e$G!$$G$OM}A[$N%O!<%I%&%'%"@_7W4D6-HOINh&JbN+=RYk!%

2.1 =>Mh$N5!G=%l%Y%k**HDL** $NLdBjE@

VHDL $dVerilog-HDL JI$N=>Mh$NHDL $rMQ$$$F$bEv=i8@$ol?DxKO%H%C%W%@%&%s@_7WKODJ$,$iJ+$C?!%7k6I=>Mh$N2sO)?^F~NO$HF1$8h&$K!$@_7W$N=i4|$+$iJ*M}E*@)Ls$r4*0F7FLJL)$K@_7W5-=R$9k3H,MW5a5lkNG"$k!%

=>Mh$NHDL GO%H%C%W%@%&%s@_7W$NI,MW@-$,9MN8$5lF$$J$$+$H$$&$H!$$=$&$GOJ$$!%<B:]!$VHDL GO<!Nh$&$J5!9=$rMQ0U7F%H%C%W%@%&%s@_7W$r;Y1g7F$$k[1]:VHDL $N3F%b%8%e!<%k$OJ#?t$N*architecture body*$r;}D3H,G-$k!%@_7W<T$O!$^$:Cj>]EY$N9b$$*architecture body*$r5-=R$7$F@_7W8!>Z$r9T$J$$!$$=lrO@M}9g@.2DG=$JCj>]EY$NDc$$bNK=g<!CV-49($F$$/!%

H3m,8=<BKO=Nh$&$J5!9=$O5!G=$;$:!$<!Nh$&$J@_7W%3%9%H$,LdBj$HJC$F$$k!%

LdBj-**1.** =i4|9)Dx$N%3%9%H

O@M}:GE,2=7O$,1EY$K:GE,2=G-$k2sO)$N5,LOKO@)8B$,$"$k!%$=$N?$a1EY$K:GE,2=$G$-$k2sO)$N5,LO$r4*0F$7!$@_7W>e%/%j%F%#%+%k$JItJ,2sO)$r1DN5!G=%b%8%e!<%kK^Ha$"$2k3Hr=E;k7F!$@_7W$N:G=i$NCJ3,$+$iLJL)$K5!G=%b%8%e!<%k$NJ,3d$r7hDj9kI,MW$,$"$k!%

$=$N7k2L!$%O!<%I%&%'%"$NF0:n$r<+A3$K5-=R9k3HFsN<!KJi6krF@$:!$$7P7$P

- 0UL#E*$K4XO"@-$N9b$$5-=R$rJ#?t$N5!G=%b%8%e!<%k$KJ,3d$7$?$j!$5U$K!$
- 0UL#E*$K4XO"@-$NDc$$5-=R$r1 DN5!G=%b%8%e!<%kK^Ha$?$j

9kI,MW$,@8$8$k!%$3$N:n6H$O?M<j$G9T$o6k$rF@$:!$%"%k%4%j%:%`!&1
%Y%k$G%P%0$,:.F~9k2DG=@-$,9b$$!%

LdBj-2. @_7WJQ99$N%3%9%H

=i4|9)Dx$GLJL)$K5!G=%b%8%e!<%kJ,3d$r9T$JC?H7Fb!$O@M}:GE,2=$N
CJ3,$G@)Ls$rK~$?$5$J$$$3H,H=L@9k3H$O40A4$KOHr1Fq$$!%$=$N>1
9gKO!$5!G=%b%8%e!<%k4V$G5-=R$N0\F0$rdO$j?M<j$G9T$&I,MW$,$"$k!%$3
Nh$&$J:n6H$O!$4{$K:n$j9~$^$l$?5-=R$KBP9kbNG"k@1K!$$d$O
$j%P%0$,:.F~$70W$$!%

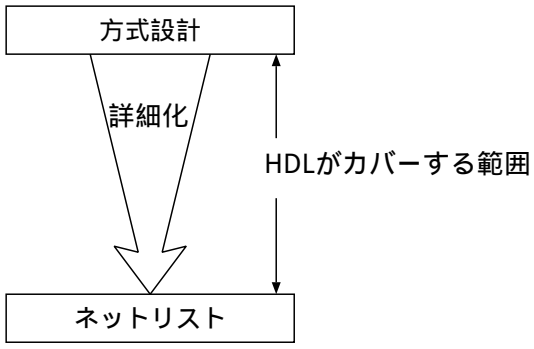
3l$O!$=>Mh$NHDL K*1k%O!<%I&&'%"$N5-=RJ}K!$K:,K\E*$JLdBj$,$"
$k!%$3liNHDL $OO@M}9g@.$r6/$/0U<1$7$F$$$k$H$$&3Hb"$j!$5-=R$N
C10L$,J*M}E*$J2sO)$K4s$j9.$F$$$kNG$"$k!%

8=:_9-$/;H$olF$$$kVHDL $dVerilog-HDL JI$NHDL $O!$5!G=%b%8%e!<
%k$rC10L$K%O!<%I&&'%"$r5-=R/O@M}9g@.$9kN$G!$FC$K5!G=%l%Y%kHDL $H8F
Pl$F$$$k!%$3$3$G5!G=%b%8%e!<%k$H$OJ*M}E*$J2sO)$H1BP1 $GBP1~$9kh$&
$JC10L$G$"$j!$%?%$_%s%0@)Ls$d2sO)$N6&M-2DG=@-$^$G9MN8$7$FJ,3d5l$?$b
NG$"$k!%

5!G=%l%Y%kHDL K*1k%O!<%I&&'%"$N5-=RJ}K!-$9Jo$A5!G=%b%8%e!<
%kKhK=$NF0:n$r5-=R7F!$8D!9$NF0:n$N=89g$H7F%O!<%I&&'%"A4BN$NF0:n
$r<B8=$9kH$$&J}K!GO!$F0:n5-=R$,5!G=%b%8%e!<%k$K6/$/0MB8$9$k!%D^
$j5!G=%b%8%e!<%k$NJ,3dJ}K!$rJQ99$9kH!$F0:n5-=R$r1 $+$idjD>5J1l
PJiJ$$!%

0lJ}$G5!G=%b%8%e!<%k$X$NJ,3d$N;EJ}$O!$%2!<%H?t$d%2!<%HCY1d$H$$C?J*
M}E*@)Ls$K6/$/0MB8$9$kbNG"$k!%=>$C$F!$O@M}9g@./:GE,2=$N7k2L$,J*M}
E*@)Ls$rK~$?5J$$$3H,J,$+$C$?$i!$5!G=%b%8%e!<%k$rJQ99$7$J1lPJ$i
$J$$!%

3N$+$K7P83$r@Q$s$@@_7W<T$JiPJ*M}E*@)Ls$r4*0F$7!$9g@.$5lk2sO)$rM=
B,7J$,$i@_7W$r?J$ak3HbA4$/IT2DG=$JLuGO$J$$!%7+$7O@M}9g@.7O/:G
E,2=7ONUJ^$G9MN8$KF~lF9g@.7k2L$r40`z$KM=B,7-k3HOHs>o$K:$Fq$G
$"$k!%=>CF!$O@M}9g@./:GE,2=7O$+iN%U%#<%I%P%/Kh$k=$@5$r40A4$KHr
1k3HOFq7$$!%



?^1: HDL $,%+%P!<$9$k@_7W9)Dx

D^$j@h$K5s2?2 DNLdBj$N860x$O!$5!G=%b%8%e!<%k$H$$$&!$<B:]$N%O!<%I%&%'%"$K6a$$$bNr%Y!<%9K7$F$$$k3HK"kNG"$k!%

:G=i$K=R$Y$?VHDL $N%H%C%W%@%&%s@_7W;Y1g$,5!G=7J$+$G$?$Nb^5K$=$3$K860x$,$"$k!%9JoA!$

- J#?t$Narchitecture body $r;}$D3H$,$G$-$k$H$$$CFb!$$=li$O5!G=%b%8%e!<%kC10L$G5-=R7J$/$FOJiJ$$!%@h$K=R$Y$?$h$&$K!$5!G=%b%8%e!<%k$O!$J*M}E*@)Ls$rK~$?$9$?$a$K0UL#E*$K4XO"@-NDc5-=Rr^Ha$?$h$&$J!$$O@M}9g@.K\0L$NU,3dC10L$G$"$k$+$i!$Cj>]EY$N9b$$architecture body $r5-=R$9kH$$$CFbL5M}$,$"$k!%
- $=$Nh&$K7$F5-=R7?Cj>]EY$N9b$$architecture body $O5!G=%b%8%e!<%k6-3&$K6/$/0MB8$9kbNG$"$k!%=>CF!$2<N.9)Dx$+iN%U%#!<%I%P%C%/KhCF5!G=%b%8%e!<%k6-3&$rJQ9$9kH!$$=li$OA4$/L5BLKJCF7^$&!%

D^$j!$5!G=%l%Y%kHDL $N:N$C?%"%W%m!<%A-9JoA8e!9JQ9$5$l$k2DG=@-$,9b$/$7$+$bJQ9$N%3%9%H$,Hs>oKBg-$$$5!G=%b%8%e!<%k$rC10L$K%O!<%I%&%'%"$r5-=R$9kH$$$&%"%W%m!<%A$O!$%H%C%W%@%&%s@_7W$N4QE@$+i_$F!$A4$/4V0c$$$G$"$C?$H8@$o6k$rF'@$J$$!%

2.2 M}A[E*$J%O!<%I%&%'%"@_7W%7%9%F%`

A0@a$G=R$Y$?5!G=%l%Y%kHDL $NLdBj$E@rF'^$($F!$?$K%H%C%W%@%&%s@_7W$r<B8=$9$kM}A[E*$J%O!<%I%&%'%"@_7W%7%9%F%`HOINh&$J>r7o$rK~$?$9Y-$+9M;!$9$k!%

%H%C%W%@%&%s$J@_7W9)Dx$H$O!$$h$jCj>]EY$N9b$$@_7W$r=y!$K>\:Y2=7F$$

$/$H$$&2aDxG"$k!%%O!<%I%&%'%"@_7W$K$*$1$k>\:Y2=$N9)DxN&$A!$HDL$,%+%P!<$9$k9)Dx$r?^1$K<($9!%

?^1$NJ}<0@_7W8e$+$i%M%C%H%j%9%H$rF@k^GN9)Dx$r;Y1g$9kN$,HDL$H$=$N=hM}7O$NLrL\$G$"$k!%9Jo$A<+A38@8l$JIG5-=R5l$?;EMM$KBP7F!$=hM}4V$NJBNs@-$d;q8;6&M-$N2DG=@-$r9MN8$7$F!$%G!<%?9=B$$d%9%F!<%89=@.$r>\:Y2=$7HDL$N%W%m%0%i%'$N7A$G5-=R$9$k!%40@.$7$?HDL5-=R$rO@M}9g@./:GE,2=7O$rMxMQ$7$F%M%C%H%j%9%H$KJQ49$9$kLuG"$k!%

%H%C%W%@%&%s@_7W$r<B8=$9k?aK$O!$3Nh$&$J>\:Y2=$N9)Dx$r8@8l%l%Y%k$G%5%]!<%H$9k3H,K>$^$7$!%9$JoAJ}<0@_7W$K6a$$Cj>]%l%Y%k$+$i<B:]$NO@M}2sO)$H1BP1$KBP1~$9kDxNCj>]%l%Y%k$^$G5-=RG-k3H,K>$^$7$!%

7+7=l@1G$OIT=-J,$G$"$k!%9b$$Cj>]%l%Y%k$N5-=R$r%5%]!<%H9k3H$K2C$($F!$@_7WJQ99$,MF0W$G$"$k3H$,5a$ail$k!%

2?8NJi$P!$%O!<%I%&%'%"@_7WGO2<N.9)Dx$+$i$N%U%#!<%I%P%C/$Khj@_7WJQ99rGwilk3H$,B?$$$+iG$"$k!%3lO%U%#!<%I%&%'%"@_7W$O!$=%U%H%&%'%"@_7WKHfY$FJ*M}E*@)Ls$,Hs>o$K6/$$$3HK5/0x9k!%$$/$iM%$l$?%"!<%-%F%/%A%c$r@_7W7F$b!$$=l,%A%C%W$K<}$^$jL\E*$N<~GH?t$GF0:n$7J1lPA4$/0UL#$O$J$$NG"$k!%

%"%k%4%j:%'%l%Y%k$NBg5,LO$J=$@5$r9TJ&>l9gKOA4$F@_7W$7D>$9$3HKJkNOd'$rF@$J$$K7F$b!$Nc$($P%Q%$%W%i%$%s!&9%F!<%8$N6-3&$rHyD4@0$9$kDxEY$N@_7WJQ99$GF0:n%l%Y%k$+$i@_7Wrd$jD>$9$H$$&3HOG-$k8B$jHr1?$$!%

$=$3$G%O!<%I%&%'%"@_7W4D6-$KFC$K5a$ailkN$O!$2<N.9)Dx$+$i$N%U%#!<%I%P%C/!&k!<%W$rG-$k@$1C;$+$/M^$(!$=$@5$N%3%9%H$r:G>.8B$K9k;EAH$_$G$"$k!%

- >eN.9)Dx$G:.F~$7$?%P%0$rJk$Y/Aa$$CJ3,$G<h$j=|$/;EAH$_
- 2<N.9)DxGN@_7WJQ99$,>eN.9)Dx$K1F6A$rM?$($J$$&$&h$&&$J;EAH$_

@_7W%7%9%F%'$,$3li$N;EAH$_rHw(lP%U%#!<%I%P%C/!&k!<%W$rC;$+$/M^$(k3H,G-$k!$@_7WJQ99$N%3%9%H$r:G>.8B$KN1$ak3H,G-$k!%

H3mG4{$K$$/D+$NF0:n%l%Y%kHDL$H$=$N=hM}7O$,5!G=%l%Y%kHDL$NLdBjE@$r2r7h$9Y/8&5f5l$F$$$k!%7$+$7$=$liO%U%#!<%I%P%C/!&k!<%W$NLdBj$r:,K\E*$K2r7h$9kbNG$J$$!%

3liNF0:n%l%Y%kHDL$N8&5f$O!$0J2<$N2D$N%"%W%m!<%A$r:NkbN,

B?$$!%

1 DO5!G=%l%Y%kHDL $N7gE@$r%"%I%[%C%/KJd*$&$H9k%"%W%m!<%A- 9JoA5!G=%l%Y%kHDL G=N^$^5-=R$9kH5-=RNL$,B?$/JCF7$^$&h&$JFCDj$N2sO)$r4J7i$K5-=RG-kh$&$9kH$$$&bNG"$k!%

Nc$($P!$Bach[2] GO!$@lMQ$N%^%/%m$rDs6!$9k3HG%O%s%I%7%'%$%/2sO)$r4J7i$K5-=RG-$kh&K7$F$$k!%$^$?Cyber[3] GO!$9%F!<%H!&%^%s$r4J7i$K5-=R$G$-!$$^$?9g@.;~$N%*%W%7%g%sKh$j;~J,3dB?=E$N=hM}$r<+F09g@.$G$-$kh&K7$F$$k!%

b&1 DN%"%W%m!<%A$O!$AH$_9~$_MQ%W%m%;%C%5JI$K5-=R$NBP>]$r8EDj$7$F!$O!<%I%&%'%"$N%F%s%W%l!<%H$Nh&JbNrM?$($kbNG"$k!%

Nc$($PAIDL[4] GO!$5-=R$NBP>]$r%Q%$%W%i%$%s%W%m%;%C%5$K9JCF$$k!%%Q%$%W%i%$%s!&W%m%;%C%5$K8EDj$9k3HG!$%Q%$%W%i%$%s!&9%F!<%8$r4J7i$K5-=R$G$-$kh&K7$F$$k!%

3N$+$K3liN%"%W%m!<%AKhCF!$5!G=%l%Y%kHDL KBP7$F5-=R$NCj>]%l%Y%k$,>e$,k3HG5-=RNL$,>/J/Jj!$7k2LE*$K@_7W%3%9%H$,:o8:5l$k!%

7+$75U$K8@$($P!$$3li$NHDL $,5!G=%l%Y%kHDL $K>!$kNO3NE@$K4X$7FN$_$G$"$k!%0MA3H7$F5!G=%b%8e!<%k$r%Y!<%9$K%O!<%I%&%'%"$r5-=R7F$$k!%2<N.9)Dx$+$i$N%U%#!<%I%P%C/$,Bg5,LO$J@_7WJQ99$K7kSIU-d9$$$H$$&LdBjE@$O2?$i2r7h5l$F$$J$$NG"$k!%

$=$3$G!$2<0L9)Dx$+$i$N%U%#!<%I%P%C/!&k!<%W$rC;$+$/M^$(!$?$N%H%C%W%@%&%s@_7W$r<B8=9k3H$rL\;X$7!$F0:n%l%Y%kHDL !Evelyn!W$r3+H/9k!%

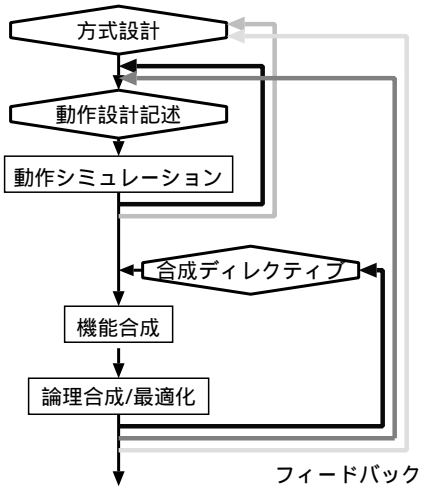
3 Evelyn @_7W$NJ}?K

2>O$G=R$Y$?5!G=%l%Y%kHDL $NLdBjE@$rF'$^$(!$K\>O$G$OEvelyn @_7W$K$"$?CF$NJ}?K$r@bL@9k!%

0J2<K\@aGO!$$^$:%H%C%W%@%&%s@_7W$r<B8=9k$?$a$N%"%W%m!<%A$r=R$Y!$$=lr<B8=9k$?$a$N%"%$%G%"$r@bL@$9$k!%

3.1 %H%C%W%@%&%s@_7W$N<B8=

Evelyn $N:G=*E*$JL\I8$O!$?$K%H%C%W%@%&%s$J%O!<%I%&%'%"$r@_7W4D6-$N<B8=G"$k!%$=$N?$aKO!$2<N.9)Dx$+iN%U%#!<%I%P%C/!&k!<%W$rC;$+$/$3H,@'HsHbI,MWG"$k!%



?^2: Evelyn $rMQ$$$?%O!<%I%&%'%"@_7W%U%m!<

2>OG_F-$?$h$&$K!$5!G=%l%Y%kHDL $GCj>]E*$J5-=R$r%5%]!<%H$7$F$$?Kb$+$+oi$:%H%C%W%@%&%s@_7W$K;jiJ$+$C$?$N$O!$2<N.9)Dx$+$i$N%U%#!<%I%P%C%/!&k!<%W$,D9$/!$@_7WJQ99$N%3%9%H$,Hs>oKBg-$+$C$?$?aG"$k!%

Evelyn GO!$%U%#!<%I%P%C%/!&k!<%W$rC;$+$/$9k$?aK<!$N%"%W%m!<%A$r:N$k:

- %b%8%e!<%k6-3&$rCj>]2=$7$F5-=R!%
- $=$3$K@_7W>pJs$rIU2C7F$$/3H$G>\:Y2=!%

3l$O0J2<$NM}M3Kh$k:A0@a$G=RY?2<N.9)Dx$+$i$ND9$$%U%#!<%I%P%C%/$NLdBj$r2r7h9k$?$aKO!$5-=R$K$*$1$k%b%8%e!<%k6-3&$H<B:]$KO@M}9g@./:GE,2=7O$KF~NO5l$k%b%8%e!<%k6-3&$H$rJ,N%$9kI,MW,$"$k!%$=$N$?$aKO!$5-=R$K$*$$F%b%8%e!<%k6-3&$,6qBNE*2a$.FOJi$J$$!%9JoA!$%b%8%e!<%k6-3&$NCj>]2=$,I,MW$G$"$k!%

7+$7C1$K5-=R$NCj>]EY$r>e2?$@$1GO!$=$3$+$i$N5!G=9g@.$,:FoHJk!%=>CFEvelyn GO!$Cj>]E*$J%b%8%e!<%k6-3&$N5-=R$+$iO@M}9g@./:GE,2=$KE,7?5!G=%b%8%e!<%k$r9g@.$9kK:]7F!$Cj>]E*$J@_7W5-=R$K9g@.%G%#%l%/%F%#%V$rIU2C9kh&K9k!%>\:Y$J@_7W>pJs$r9g@.%G%#%l%/%F%#%VH7$FM?$(k3HG!$5-=R$NCj>]EY$N9b$5$H!$9g@.G=NO$N%H%l!<%I%*%U$r9b$$%l%Y%k$G%P%i%s%9$5;$k!%

3Nh&$J%"%W%m!<%A$r:Nk3HG!$%O!<%I%&%'%"@_7W%U%m!<$O?^2Nh$&$K$&$KJk!%

@_7W$N=i4|CJ3,$G$O!$%O!<%I%&%'%"$NF0:n$N$_$r5-=R9k!%3NH-5!G=%b%8%e!<%kNh$&$K<B:]$NO@M}2sO)$K6a$$%l%Y%k$N%b%8%e!<%k$GOJ$/!$F0:n%b%8%e!<%k$H$$$&hjCj>]E*$J2t$rC10L$K5-=R$9$k!%%O!<%I%&%'%"$rF0:nC10L$G5-=R$9k3HG!$F0:n@_7W5-=R$NCf$K5!G=%l%Y%k$N@_7W>pJs$,F~$j9~$'I,MW$rJ/$9!%

F0:n5-=RKBP7$FF0:n%7%_%e%l!<%7%g%s$r$7!$F0:n%l%Y%k$N%P%0$r<h$j=|$/!%F0:n>pJsN_$N4J7i$J5-=R$N8!>Z/%G%P%C%0$JNG8zN(NI$/9T$J$($k!%

$=$7$F!$Cj>]E*$JF0:n5-=R$K8e$+$iIU2C9k$H$$&7AGh$j>\:Y$J5!G=%l%Y%k$N@_7W>pJs$r5-=R9k!%

>\:Y2=5l$?@_7W5-=R$r5!G=9g@.!$$=7FO@M}9g@./:GE,2=9k!%9g@./:GE,2=7k2L$,J*M}E*@)Ls$rK~$?$5J>l9gKO>eN.9)DxKLaC$F@_7WJQ99$9k3HKJk$,!$B?/$NJQ99$JiP9g@.%G%#%l%/%F%#%VN_$rJQ99$9lPh/!$F0:n5-=R$K$^$G<j$r2C$(kI,MWO$J$$!%

3Nh&$K%U%#!<%P%C/!&k!<%W$r:G>.8B$KM^$(k3HG%H%C%W%@%&s@_7W$r<B8=$9$k!%

0J2<GO3N%"%W%m!<%A$N80$HJk%b%8%e!<%k6-3&$NCj>]2=$H9g@.%G%#%l%/%F%#%VKD$$Fhj>\$7$/bL@$9$k!%

3.2 %b%8%e!<%k6-3&$NCj>]2=

Evelyn NBg-$JFCD'$N1 DO!$%O!<%I%&%'%"$rhj9b$$Cj>]%l%Y%k$G5-=R$G$-$k$H$$&E@G"$k!%6qBNE*$K$OEvelyn $O!$0J2<$NCj>]2=$r%5%]!<%H9k:%G!<%?$NCj>]2= Ns5s7?!$B?<!85$NG[Ns7?!$9=BBNJ$I!$Cj>]EY$N9b$$%G!<%?7?$r%5%]!<%H$9$k!%$=li$O(H>)<+F0E*$K%S%C%HNs$K9g@.$5lk!%%b%8%e!<%k6-3&$NCj>]2=

%Q%$%W%i%$%s$NCj>]2= J#?t$N%9%F!<%8KEOk0lO"$NF0:n$r<+A3$K5-=R$7!$$=$N5-=R$+$i%Q%$%W%i%$%s$r(H>)<+F0E*$K9g@.$9$k!%

$=$NB>$N%b%8%e!<%k$NCj>]2= F0:nC10L$K%O!<%I%&%'%"$r5-=R9k!%5!G=9g@.;~$K5!G=%b%8%e!<%k$K2~aF%^%C%T%s%0$9$k!%

4pK\E*$J%]%j7!<$O!$F0:n$KD>@\1F6A$rM?$(J;v9'$r5-=R$9kI,MWrJ/$9!$$H$$&3HG"$k!%

Nc$($P!$Cj>]%G!<%?%S%C%HNs$X$N%^%C%T%s%0J}K!!$O@M}$N@5/Ii$NULJI$O!$2sO)$NLL@Q$K$O1F6A$rM?$($k$,!$=lKhC$FF0:n$K1F6A$r5Z$\$9bNGO$J

$$!%3Nh&JbNOF0:n5-=R$+$i@Z$jN%$7!$9g@.%G%#%l%/%F%#%V$H7FM?$(
lP@_7WJQ99$OMF0W$HJk!%

$^$?%Q%$%W%i%$%s$bCj>]2=$9$k!%%Q%$%W%i%$%s$N%9%F!<%89=@.$O3N$+$KF0:n
KBg-$/1F6A$rM?$($kbNG"k,!$0lJ}$GJ*M}E*@)LsKb6/$/0MB8$9kb$N
G"$k!%%Q%$%W%i%$%s$r!$0lO"$NF0:n$H!$%9%F!<%89=@.$r;X<($9$k@_7W>pJs$G
I=8=9kh&K9lP!$J*M}E*@)Ls$Khj@_7WJQ99rGwil?>l9gKbF0:n$r
JQ99$;$:$KBP=h$G$-$k!%

5iK=$NB>$N%b%8%e!<%k6-3&$bCj>]2=$9$k!%F0:n%b%8%e!<%k$rC10L$K%O!<
%I%&%'%"$r5-=R$7!$5!G=9g@.;~$K5!G=%b%8%e!<%k$K%^%C%T%s%0$9$k!%%^%C%T%s
%0$NJ}K!$O9g@.%G%#%l%/%F%#%VH7$FM?$($k!%$3$&$9lP!$5!G=%b%8%e!<%k6-
3&$NJQ99$,F0:n$K1F6A$r5Z$\$5$J$$!%

3.3 9g@.%G%#%l%/%F%#%V

Nc$($P!$0l8}$K5-212sO)$H$$$CFb RAM!$%U%j%C%W%U%m%C%W!$%i%C%AJI
MM!9$J<B8=J}K!$,9M$($ilk!%5!G=9g@.$^$GKO6qBNE*KINh$&$K<B8=9k
$+!$@_7W>pJs$rM?$(kI,MW,$"$k!%

H3mG!$$3Nh$&$J@_7W>pJs$O%O!<%I%&%'%"$KBP7F4pK\E*KO@-G=0J30
$NE@$G1F6A$r5Z$\$5$J$$!%$=$3$G Evelyn GO!$$3li$N;XDj$rF0:n5-=RCf$K5-
=R9kNGOJ$/!$5!G=9g@.;~$N9g@.%G%#%l%/%F%#%V$H7FM?$($k$H$$$&%"%W
%m!<%A$r:N$k!%3N%"%W%m!<%AKh$j!$J*M}E*@)Ls$rK~$?9?aK@_7WJQ99$,
I,MWKJC?>l9gGb!$F0:n5-=R$KA4$/1F6A$rM?$($k3HJ/@_7WJQ99$r9T$J
$&$3H,G-$k!%

3N9g@.%G%#%l%/%F%#%V$O!$C1$K9g@.;~$N%*%W%7%g%sH7$FM?$(kNGO$J
$/!$8@8l;EMM$N0lIt$H7F5,Dj9k!%8@8l;EMMH7$F5,Dj$7!$$=$N%;%^%s%F%#
%/%9$rL@3N$K9k3H$G!$5-=R$N0UL#$,=hM}7O$K0MB8$7$J$$$h$&$K9k!%3&
9l$P5-=R$N%]!<%?%S%j%F%#$,9b$^$j!$@_7W<T$,=hM}7O$NJJ$KG:$^5lk3$H
$,$J$/$J$k!%

3.4 %Q%$%W%i%$%s$NCj>]2=

0J>e!$Evelyn $r@_7W$9kK$"$?CF$NJ}?K$K$D$$$F=RY?!%$3$3$GFI<T$K
Evelyn $N%$%a!<%8rDOsGbi&$?$a$K!$%Q%$%W%i%$%s$rCj>]2=$7$F5-=R$9$k
J}K!$r>R2p$9$k!%

$$x_1 <= f_0(x_0); \quad (1)$$
$$x_2 <= f_1(x_0); \quad (2)$$
$$x_3 <= f_2(x_1); \quad (3)$$
$$x_4 <= f_3(x_3, x_2); \quad (4)$$
$$x_5 <= f_4(x_3); \quad (5)$$
$$x_6 <= f_5(x_4); \quad (6)$$

?^3: 5-=R1

Evelyn K*1k%Q%$%W%i%$%s$N5-=RJ}K!$O!$4JC1$K$$&$H

1. 0lO"$N=hM}$r;~4VJ}8~$K5-=R$7$F!$
2. %9%F!<%86-3&$N0LCV$r;XDj$7!$
3. %Q%$%W%i%$%s!&i%C%A$N<B8=J}K!$r;XDj9k!$

$H$$&bNG"$k!%

%Q%$%W%i%$%s$N5-=RK!$rDL7F!$@h$K5s2?2 DNJ}?K- %b%8%e!<%k6-3&$N Cj>]2=$H9g@.%G%#%l%/%F%#%VKhCF%O!<%I%&%'%"@_7W9)Dx$,$I$&JQ$okN$+!$ $H$$&3H$r=R$Y$k!%

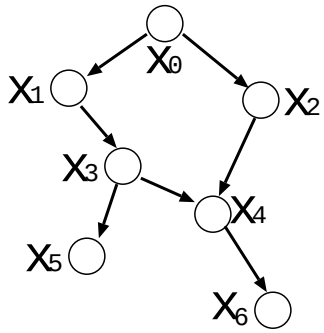
3.4.1 ;~4VJ}8~$NF0:n5-=R

Evelyn GO!$F0:n$r;~4VJ}8~$K5-=R$9$k!%$3$NF0:n5-=RCf$N3F=hM}4V$N;~4V 4X78$O!$%G!<%?0MB84X78$KhC$FH>=g=xE*$K5,Dj5l$k!%

;~4V4X78$,H>=g=xE*$JNG !3N=hM}$,;O$^$kA0$K!D!W$d !$3$N=hM}$H3N =hM}$N4V$K!D!WJI;~4V4X78$K4X$7$F=@Fp$J5-=R$,2DG=$HJk!%$^$?B?$/$NF0 :n%l%Y%kHDL GOF0:n5-=R$r9T$J$&;~E@$G%9%F!<%89=@.$^$G7hDj7JlP Ji$J$$,!$Evelyn GO=c?h$KF0:n$@1r5-=RG-$k!%

?^3$O!$Evelyn $NF0:n5-=R$NH4?hG"$k!%$3$3$K$O?^4$N%G!<%?%U%m!<!&0 %i%U$K<($9h&$J0MB84X78$,$"$k!%$=$N$?$a3$N5-=R$+iO(1) $H(3)!$(2) $H (4) JI$N4V$N=g=x4X78N_$,5,Dj5l!$(2) $H(3) JI$N4VKO=g=x4X78$O5, Dj5l$J$$!%

3Nh&$KH>=g=xE*$J;~4V4X78N_$r5,Dj$9k3HG!$%"%k%4%j%:%'E*$J@) Ls$,$J$/!$J*M}E*$J@)Ls$N$_$G=g=x$r7hDj$9lP$h$$h$&$J=hM}4V$N=g=x$rF0 :n@_7W;~$KL5M}$K7hDj9kI,MW$,$J$/$J$k!%



?^4: 5-=R1 $N%G!<%?%U%m!<!&0%i%U

$$x_1 <= f_0(x_0); \quad (1)$$
$$x_2 << f_1(x_0); \quad (2)$$
$$x_3 << f_2(x_1); \quad (3)$$
$$x_4 <= f_3(x_3, x_2); \quad (4)$$
$$x_5 <= f_4(x_3); \quad (5)$$
$$x_6 << f_5(x_4); \quad (6)$$

?^5: %9%F!<%86-3&$rsingal $G5-=R

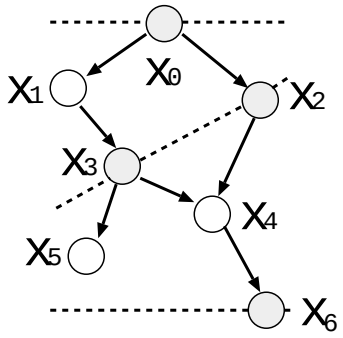
3.4.2 %Q%$%W%i%$%s$N<+F09g@.

?^3Nh$&$J7A$G5-=R$5l?F0:n$O!$<B:]$N%O!<%I%&%'%"$G$O1 D^$?$OJ#?t$N%9%F!<%8$KJ,3d7F<B9T5lk3HKJk!%Evelyn GO3N%9%F!<%8$N6-3&$rJQ?tKh$K;XDj$9$k:0lO"$NF0:nNCfG%9%F!<%86-3&H7$?$$2U=j!$$9Jo$A%Q%$%W%i%$%s!&i%C%A$rA^F~7?$$2U=j$rFC<l$JJQ?t$rMQ$$$F5-=R9k!%

Evelyn KO**signal**(%7%0%J%k) $H**singal**(%7%s%,%k) $H$$$&2 <oN'$N%G!<%?!&%*%V%8%'%/%H$,$"$k!%0lO"$NF0:n$NCf$G!$%Q%$%W%i%$%s!&i%C%A$rA^F~$7$F%9%F!<%86-3&$H7?$$2U=j$Osingal $G5-=R$7!$$=$l0J30$N2U=j$Osignal KhGF5-=R9k!%

%Q%$%W%i%$%s$N9g@.$O0J2<Nh$&$K9k:F0:n$N@hF,$+$i=g$K8=ol$ksingal $r7k$V3H$G!$%G!<%?%U%m!<!&0%i%UNCfK“Ey9b@~” $r5,Dj$9$k!%$=7F!$$3$N“Ey9b@~” $r%9%F!<%86-3&$H9k%Q%$%W%i%$%s$r9=@.$9$k!%$3NH$-singal $NA08e$N4pK\E*$JF14|[1] $r<B8=$9k?aN%O%s%I%7%'%$%/2sO)$r<+F09g@.9k!%

[1] M-8z%S%C%H!$%i%$%H%$%M!<%V%k$JIKhk4JC1$JF14|!%



?^6: %G!<%?%U%m!<!&0%i%U$K“Ey9b@~” $rDj5A

Nc$ ($P!$?^3$NF0:n$K$*$$$F$(x_2!$3)$ $N0ICV$G%9%F!<%8$r6h@Z$j$?$$>l9g!$?^5$Nh&K=li$rsingal $rMQ$$$F5-=R9k!%$?$@$7?^Cf$N<<$Osingal XNBeF~$rI=$9!%

9k$H%G!<%?%U%m!<!&0%i%U$K?^6$NE@@~$G<(7?h&$J“Ey9b@~” $r0z$/3H$,$G$-$k!%3N“Ey9b@~” $r%9%F!<%86-3&$H9kh&$J%Q%$%W%i%$%s%s$r9g@.9k!%3NH-$x_2!$3$NA08e$KF14|N?aN2sO)$r<+F09g@.$9$k!%

3Nh&$J7A$N%Q%$%W%i%$%s5-=RJi$P!$O@M}9g@.7OJI$+$i%U%#!<%I%P%C%/$,$"G?>l9gJI$N@_7WJQ99$hMF0WG"$k!%Nc$($P!$%?%$%_%s%0@)Ls$JIN$?$a!$$(x_2!$3)$ H7$F$$?%9%F!<%86-3&$r(x_1!$3)$ $KJQ99$7$?$$H9k!%Evelyn GO3Nh&$JJQ99$O!$$x_2$rsingal $+$isignal $KJQ99$7$F!$BeojKx_1rsingal K9k@1G$h$$!%JQ99N?aN%3%9%HO[Hs$I0 $H$$$CFh$$$@m&!%

3.4.3 5!G=%l%Y%kHDL $HHf3S$7$F

5F!$?^5$Nh&$J%Q%$%W%i%$%s5!G=%l%Y%kHDL $G5-=R$9kHINh&KJkNG"m&$+!)?^7$KVHDL Kh$k5-=RNc$r<($9!%4JC1$N$?a?^$K$O>eN.%9%F!<%8$N$_$r5-=R7?!%

?^7$OVHDL Kh$kE57?E*$J%9%F!<%H!&^%7%s$N5-=RNc$G!$?^8$Nh&$J2sO)$r<B8=7F$$k!%9JoA%W%m%;%9control $,30It$+iN%j%/%(%9%H?.9fJI$r<u$1$F%9%F!<%8$N@)8f$r9T$J$&!%%W%m%;%9control $K@)8f$5lF%W%m%;%9main $,$x_0$+$ix_2!3r@8@.9k!%

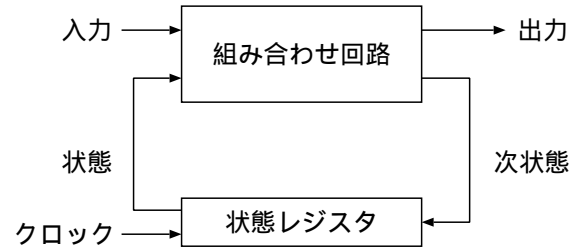
3NNc$+$i5!G=%l%Y%kHDL $N5-=R$NCj>]EYNDc5!$5-=RNL$NB?5,<B46G-$k!%0lHL$K5!G=%l%Y%kHDL GO%9%F!<%H!&^%7%sr3Nh$&$K>uBVA+0\%0%i%UH7F5-=R7J1lPJiJ$$!%

5i$K@_7WJQ99$N%3%9%H$bHs>o$KBg$-$$$3H,J,$+$k!%@hDx$HF1MM$K?^6$K

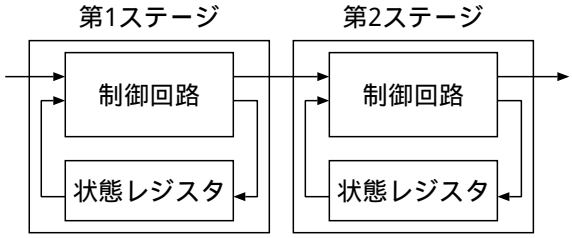
```
control : process( req_i, ack_i, state )
begin
    if state = FULL then
        ack_o <= req_i and ack_i;
        if ( ack = '1' ) and not( req_i ) then
            state_nxt <= EMPTY;
        else
            state_nxt <= FULL;
        end if;
    else
        ack_o <= req_i;
        if req_i = '1' then
            state_nxt <= FULL;
        else
            state_nxt <= EMPTY;
        end if;
    end if;
end process control;

main : process( rst, clk )
    variable x1 : std_logic;
begin
    if rst = '1' then
        state <= EMPTY;
    elsif clk'event and clk = '1' and clk'last_value = '0' then
        state <= state_nxt;
        if ack_o = '1' then
            x2 <= not( x0 );
            x1 := x0;
            x3 <= x1;
        end if;
    end if;
end process main;
```

?^7: VHDL Kh$k5-=R



?^8: VHDL 5-=R$,<B8=$9$k%9%F!<%H!&^%7%s



?^9: 5!G=%b%8%e!<%k9=@.

$*$$F(x_2!x_3)H7$F$$$?%9%F!<%86-3&$r($x_1$!$x_2$)$KJQ99$9$k>19g$r9M$($k!%

?^7$N5-=R$KBP7F$=$Nh&$JJQ99$r9k>19g!$%W%m%;%9main$H!$2<N.%9%F!<%8$NF1MM$N%W%m%;%9$H$N4V$G=hM}$rcut & paste$KhC$F0\F0$7J1lPJi$J$$!%3lO%P%0$N:.F~$9$k4m81@-$N9b$$:n6HG"$k!%<B:]!$$h$jJ#;($J5-=RKBP7F3Nh$&$JJQ99$r9T$J$&>19g!$7k6I1$+$i=q$-D>$9$3$HKJ$C?$H$$$&>19g$,B?!9$"$k!%

@_7WJQ99$,:$FqJN$O!$VHDLGO5!G=%b%8%e!<%k6-3&$r@h$K7hDj7F!$$=lr%Y!<%9$KF0:n$r5-=R9k$?$aG"k3NNcG$OF0:n$r=q$/A0$K%9%F!<%89=@.!$%9%F!<%8$NFbIt9=@.$r@_7W$7$F!$5!G=%b%8%e!<%k9=@.rNc($P?^9$Nh&K9kH7hDj7J1lPJiJ$$!%

H3m,3N5!G=%b%8%e!<%k9=@.$OJ*M}E*@)Ls$K6/$/0MB8$9k?$a!$O@M}9g@./:GE,2=7O$+$i$N%U%#!<%I%P%C/$Khj:F9=@.7J1lPJiJ$$3NN($,6K$a$F9b$$!%5!G=%b%8%e!<%k$N9=@.$,JQok$H!$$=lr%Y!<%9$K5-=R$7$F$$$?F0:n$bJQ99$;6k$rF@$J$$!%

$=$lKBP7Evelyn$O!$F0:n$r%Y!<%9$K5-=R$7!$$=$N>e$Ksingal$Hsignal$G5!G=%b%8%e!<%k9=@.$K4X$9$k@_7W>pJs$rIU2C9kh&KJCF$$$k!%3N?$a!$O@M}9g@./:GE,2=7O$+$i$N%U%#!<%I%P%C/$Khj5!G=%b%8%e!<%k9=@.$rJQ99$9$k>19g$K$O!$signal$Hsingal$N0LCVN_JQ99$9$lP/F0:n5-=R$^$GJQ99$9$k

I,MW$,$J$$!%

J*!$VHDL KHfY$FEvelyn $N5-=RNL>/$J$$860x$N1 DH7F!$singal $,9b5!G=$G$"$k$H$$$&3H$,5s$2il$k!%VHDL GO3F%9%F!<%8$K>uBV$r;}$?$;$F%9%F!<%84V$NF14|$r<B8=7F$$k$,!$singal O3$NA4$F$r0E<(E*$K<B8=9k!%

3Nh&$J9b5!G=$JbN$r%W%j%_%F%#%V$H7F<BAu9k$H8B$il?<oN'$N2sO)$7$+5-=R/9g@.$G$-$J$$$H9M$(B$k8~$-$b$"$k$+$b7l$J$$$!%7+$7!$singal $N9g@.J}K!$O8e$G9g@.%G%#%l%/%F%#%V$Khj:Y$+$/;XDjG-$k!%9g@.%G%#%l%/%F%#%V$N>\:YKD$$$F$O6>O$G=RYk!%

4 Evelyn $N35G0

K\>OGO!$Evelyn K*1kCj>]E*$J%O!<%I%&%"%F0:n5-=RKD$$$F!$$=$N4pK\$HJk35G0KD$$$F=RYk!%

4.1 %b%8%e!<%k6-3&$NCj>]2=

4.1.1 %b%8%e!<%k$H%U%!%s%/%7%g%s

Evelyn GOF0:nC10L$K%O!<%I%&%"%$r5-=R9k!%9JoA!$F0:n$N<gBN$r%b%8%e!<%k$H7F5-=R$7!$%b%8%e!<%k$,9T$J$&F0:n$r%U%!%s%/%7%g%sH7$F5-=R$9$k!%

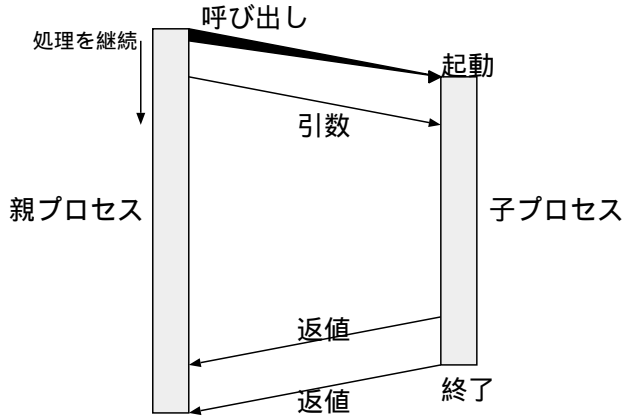
$3$3$G$$$&%b%8%e!<%kHOF0:n%b%8%e!<%kG"$k!%$9Jo$A5!G=%b%8%e!<%k$H$O4X78$J$$!$$"$/$^$GF0:n$N<gBNG"$k!%5!G=9g@.;~$KF0:n%b%8%e!<%k$r<+:_$KJ,3d/E}9g7F5!G=%b%8%e!<%k$X%^%C%T%s%0$9k3H,G-$k!%F0:n%b%8%e!<%k$O!$F0:n$r5-=R7d$9$$$h$&$K9=@.9lPh$$!%

%U%!%s%/%7%g%sKO1$D1$D$NF0:n$r;~4VJ}8~$K5-=R$9$k!%%O!<%I%&%"%$rF0:nC10L$K5-=R$G$-$k$?$a!$J#?t%5%$%/%kKEOkh&$JF0:n$bHs>o$KAGD>$J7A$G5-=R$9k3H,G-$k!%

Evelyn GO3F%b%8%e!<%k$,8_$$$KAj<j$N%U%!%s%/%7%g%s$r5/F0$79g$&3H$G%O!<%I%&%"%$rF0:n$r%b%G%k2=$9$k!%$D$^$j!$Evelyn GODL?.$r%U%!%s%/%7%g%s8F$S=P7KCj>]2=9k!%

4.1.2 %U%!%s%/%7%g%s

A0=R7?h&$K!$Evelyn GO1O"$NF0:n$r%U%!%s%/%7%g%sH7$F5-=R$9$k!%%b%8%e!<%k$,8_$$$K%U%!%s%/%7%g%s$r8F$S=P$79g$&3H$G%O!<%I%&%"%$rF0:n$r%b%G%k2=$9$k!%



?^10: %W%m%;%9

%U%!%s%/%7%g%s8F$S=P$7KhCF9TJolk1 2s$N%U%!%s%/%7%g%s$N<B9T$r%W%m%;%9$H8F$V!%

Evelyn $N%U%!%s%/%7%g%s$, VHDL K*1k4X?tJI$H0[$J$kE@$O!$Evelyn $N%U%!%s%/%7%g%s$K$O!$B?%5%$%/%k$rMW9k=hM}$b5-=R$G$-$k$H$$$&E@G"$k!%$3N3HO%W%m%;%9$,J#?t%9%F%C%W$r$+$1$F<B9T$5lk$H$$$&3H!$$=7F%7%9%F%'FbKOJ#?t$N<B9TCf$N%W%m%;%9$,B8:_$7F@$k!$$H$$$&3H$r0UL#$9$k!%

%U%!%s%/%7%g%s$,8F$S=P5lkH!$8F$S=P$7B&%W%m%;%9$H8FPl$?%W%m%;%9$OJBNs$K<B9T$5lk!%9JoA!$%U%!%s%/%7%g%s8F$S=P7N8e!$8F$S=P$7B&%W%m%;%9$O%U%!%s%/%7%g%s$N40N;$rBT$?$:$K8eB3L?Na$N<B9T$rB3$1!$JVCM$,I,MWKJC?;~E@$G<B9T$r%V%m%C%/9k!%$^$?!$8F$Pl?%W%m%;%9$O!$JVCM$,MQ0U$G$-$?;~E@G8F$S=P$7%W%m%;%9KCMrJV$9!%$J$*!$JVjCM,J#?t$"$k>19gKO!$$=li$,JL!9$KJV5lk3H,$"$k(?^10;2>H)!%

J#?t%5%$%/%k$K5Z$V%W%m%;%9$O!$singal XN=q$-9~$_0ICV$G$$$/D+$N%9%F!<%8$KJ,3d5l$k!%%9%F!<%8$KJ,3d5l$?%W%m%;%9$O%Q%$%W%i%$%sH7$FF0:n$9$k!%%W%m%;%9$N<B9T%b%G%k$N>\:Y$O!$1.2@a$G=RYk!%

4.1.3 @)Ls%U%!%s%/%7%g%s

%U%!%s%/%7%g%s8F$S=P$7$G%O!<%I%&%'%"$r%b%G%j%s%0$9$k>19g!$F10l%b%8%e!<%k$KBP7F%U%!%s%/%7%g%s$,F1;~$K8F$S=P$5l?>19g$N=hM}$,LdBjHJ$k!%$9Jo$A!$0lHL$N%=%U%H%&%'%"$N%W%m%0%i%'JiP3Nh$&$J>19gO=li$,GSB>E*$K<B9T5llP$h$$$3H,IaDLG"k,!$%O!<%I%&%'%"$N>19gKO$=$lir$^$HaFE}0lE*$K=hM}$9kI,MW,$"$k!%

Evelyn GO$=$Nh&$J>l9g$N=hM}$r@)Ls%U%!%s%/%7%g%s$H8F$VFCJL$J%U%!%s%/%7%g%s$rMQ$$F5-=R9k!%@)Ls%U%!%s%/%7%g%s$,F1;~$K8FPlkH@)Ls%U%!%s%/%7%g%s$,12s<B9T$5lF!$F1;~8F$S=P7rE}0lE*$K=hM}$9$k!%

4.1.4 %U%!%s%/%7%g%s8F$S=P$7$N%;%^%s%F%#%/%9

$"$k%b%8%e!<%kKBP7$FF1;~$KJ#?t$N%U%!%s%/%7%g%s$,8F$S=P$5l?>l9g$N%;%^%s%F%#%/%9$r0J2<K^Ha$k!%

$"$k%b%8%e!<%kKBP7$F!$

- F1$8%U%!%s%/%7%g%s$,F1;~$K<B9T$5l?$i!$$=N&ANIl$+1$D$,Hs7hDjE*$KA*Br5l%U%!%s%/%7%g%s$,<B9T$5lk!%
- 0[Jk%U%!%s%/%7%g%s$,F1;~$K8F$S=P$5l?$i!$
  - b7%b%8%e!<%k$,@)Ls%b%8%e!<%k$JiP$=$liOE}0lE*$K=hM}$5lk!%
  - b7%b%8%e!<%k$,@)Ls%b%8%e!<%k$G$J$$JiP$=$liOF1;~$K=hM}$5lk!%

F10l$N%U%!%s%/%7%g%s$rF1;~$K=hM}$7$?$$!$$"$k$$OE}0lE*$K=hM}$7$?$$>l9gKO!$%U%!%s%/%7%g%s$NG[Ns$rMQ$$k!%%U%!%s%/%7%g%s$rG[Ns$H7FDj5A9k$H!$G[Ns%5%$:$@$1F1;~!$$"$k$$OE}0lE*$K=hM}$G-kh$&$KJk!%

4.1.5 %$%K%7%c%k!&U%!%s%/%7%g%s

:G8e$K%$%K%7%c%k!&U%!%s%/%7%g%sKD$$$F@bL@9k!%%$%K%7%c%k!&U%!%s%/%7%g%s$H$O!$:G=i$K<B9T$5lk%U%!%s%/%7%g%s$G7O$r;OF0$5$;$kLr3d$r;}$D!%%b%8%e!<%k$O%$%K%7%c%k!&U%!%s%/%7%g%s$r1$D;}$D3H$,$G$-$k!%7O$rF0:n$5$;$k$H!$$^$::G>e0L%b%8%e!<%k$N%$%K%7%c%k!&U%!%s%/%7%g%s$,<B9T5l$k!%%b%8%e!<%k$,$"$k%b%8%e!<%k$NFbIt%b%8%e!<%k$H7F%$%s%9%?%s%92=$5lF$$$k>l9g!$FbIt%b%8%e!<%k$N%$%K%7%c%k!&U%!%s%/%7%g%s$C0ULr;}$?$J$!%0J>e!$%b%8%e!<%k$H%U%!%s%/%7%g%s$K$D$$$F=RY?!$Evelyn $O%O%$%l%Y%k$J;kE@$G$O%b%8%e!<%k$,8_$$K%U%!%s%/%7%g%s$r8F$S=P7"$&$3HGF0:n9k!%

4.2 %U%!%s%/%7%g%s$NF0:n

K\@aGO!$Evelyn Nh$j%m!<%l%Y%k$NF0:n-%U%!%s%/%7%g%sFbIt$NF0:n%b%G%kKD$$F@bL@9k!%

4.2.1 singal $Hsignal

3>OGb=RY?h&$K!$Evelyn KOsingal $Hsignal $N2<cN‘$N%G!<%?%*%V%8%’%/%H$,$"$k!%

```
()modA::funcB(){
        ⋮
  data << xxx;
        ↑
  (data=xxx) $N%i%$%U%?%$%`
        ↓
  data << yyy;
}
```

?^11: %G!<%?$N%i%$%U%?%$%`

IAib5-21$rJ];}$9%k$?$aNbNG$"$k$,!$N><TKOBg$-$J0c$$$,$"$k!%$=$l$O!$singal $QF14|5!9=$rHw$(;}$D$H$$$&E@G"$k!%$9Jo$Asignal KBP7FO>o$K<+M3KFI_=q$-G-!$>e=q$-5lk^$G$$$D$^$GbCMrJ];}7F$$$kNKBP$7!$singal KBP7FO<!Nh$&$J@)Ls$,$"$k!%

- F10l%5%$%/%k$G8E$$CM$r;2>H$7J,$i?7$7$$CM$r=q$-9~$`$3H,G-$k!%
- 8E$$CM$,$^$@;2>H$5lk2DG=@-$,$"$k>19g$K$O!$?7$7$$CM$r=q$-9~$`$3H,G-$J$$!%
- A0$N%5%$%/%k$GM-8z$JCM$r=q$-9~$^$lJ+$C?singal NCMO;2>H9k3H$,G-$J$$!%

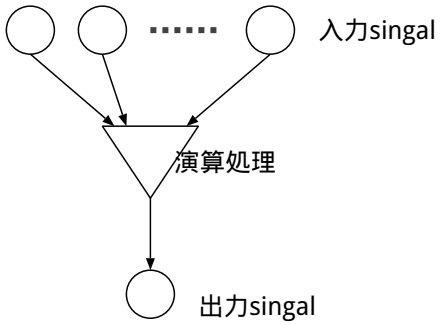
singal XN=q$-9~$_/;2>H$,$G$-$J$>19g$K$O!$<B9T$r%V%m%C%/$7!$<!$N%5%$%/%k$Kb&1EY<B9T9k!%

signal KBP7FO(1) CM$NBeF~(BeF~1i;;R$O<=)(2) CM$N;2>H$N2DN%"%/%;%9$,2DG=$G$"$k!%0lJ}!$singal KBP7FO(1) BeF~(BeF~1i;;R$O<<)(2) FI$_=P7K2Co($F!$(3) M-8zJCMr;}CF$$$k$+$N%A%'%C%/(1i;;R$O?)$N3DN%"%/%;%9$,2DG=$G$"$k!%

5F!$singal KD$$$F!CM,;2>H5l$k2DG=@-$rH=Dj7J1lPJiJ$$!%3lO=hM}7O$,<+F0E*$K9TJ&!%

"%W%m%0%i%'Cf$G;2>H$5lk2U=j"$O@EE*$KH=DjG-$k!%$9Jo$A!$$=$Nsingal $,%U%!%s%/%7%g%s%m!<%+%k$JJQ?tG"$k>19g!$$=$N%U%!%s%/%7%g%sFb$G$=$Nsingal XNBeF~$+$i<!N=$Nsingal XNBeF~$^G,$=$N%G!<%?$N%i%$%U%?%$%`G"$k(?^11;2>H)!%=>CF!$$=$N4V$K$"$k$=$Nsingal XN%"%/%;%9$,8E$$CM$r;2>H$9$k!%

%9%3!<%W$,%b%8%e!<%kFb$G$"$kh&$Jsingal $N>19g$O<!Nh$&$K7F7hDj



?^12: <B9T$NC10L

9k:

1. :G>e0L%b%8%e!<%k$N%$K%7%c%k!&U%!%s%/%7%g%s$+$iA4FN%U%!%s%/%7%g%s$rE83+$7$F0MB8%0%i%U$r@8@.9k!%
2. 0MB8%0%i%U$ND:E@$+$iF1$8%l%Y%kK"$ksingal $r7k$V“Ey9b@~” $rDj5A$9$k!%
3. %9%3!<%W$,%b%8%e!<%kFb$G$"$ksingal KBP7$F!$:G=i$N=q$-9~$_$+$i<!$N=q$-9~$_$^$GK=NCMr;2>H9kbN$,:G=i$N=q$-9~$_7k2L$r;2>H$9kbNG$"$k!%

J*!$:G=i$K=q$-9~$^lkA0KCMr;2>H7?>l9gKOITDjCM$,FI$^lk!%$^$?F10l$N“Ey9b@~” >e$GJ#?t$N2U=j$+$i=q$-9~$^$l$k>l9g$O!$$=liN&$A$$:l+1 D,Hs7hDjE*$KA*Br$5$l=q$-9~$^$l$k!%

4.2.2 %U%!%s%/%7%g%sFbIt$NF0:n%b%G%k

Evelyn $N%W%m%0%i%'$O!$signal $rC10L$K<B9T5l$k!%$9JoA"$ksingal $y KBP7$F!$$=NCMr7W;;9k$?$a$N4X?t$r<!Nh$&$KDj5A$7!$$3lr<B9T$NC10L$H9k!%

$$y << f(x_0, \cdots, x_n)$$

0J9_GO3l$r<B9T%f%K%C%H$H8F$V!%?^12$K<B9T%f%K%C%H$r<($9!%

%5%$%/%kKh$K!$Ev3:%5%$%/%k$G<B9T$5lkY-A4FN<B9T%f%K%C%HKD$$F!$

1. F~NOsingal NCfKM-8zJCMr;}$?$J$$$bN,$"$k$+!$=PNOsingal $,%V%m%C%/$5lF$$$kJi$P!$%5%9%Z%s%I9k!%
2. A4FNF~NOsingal $,M-8z$JCM$r;}$A!$=PNOsingal XN=q$-9~$_$,%V%m%C%/$5lF$$$J$$$J$i!$F~NOsingal $+$iCMrFI_=P$7!$1i;;=hM}$r<B9T$7!$7k2L$r=PNOsingal $K=q$-9~$'!%

$H$$&=hM}$r9T$J$&!%

```
module %b%8%e!<%k<1JL;R{
    generic:
    private:
    public:
    configuration:
    port:
};
```

?^13: %b%8%e!<%kIt$N9=@.

Evelyn 5-=R$O!$@EE*$K9=C[$5lk<B9T%f%K%C%H$NM-8~%0%i%U$H9M$($ilk!%
Evelyn 5-=R$rF0:n$5$;$kHO!$$3$NM-8~%0%i%U$KBP7F%G!<%?$rN.$9$3$H$KB>
Ji$J$$!%

%U%!%s%/%7%g%sFbIt$NF0:n%b%G%k$H!$%b%8%e!<%k$NF0:n%b%G%k$N4X78$O0J2<
Nh$&$KJC$F$$k:

Evelyn $N%U%!%s%/%7%g%s$O!$0lHL$N%W%m%0%i%_%s%08@8l$N4X?t$Nh&$K8F$S
=P$7;~$KF0E*$K%G!<%?NN0h$,3NJ]5lkh$&$JbNGO$J$$!%%G!<%?NN0h$OA4
$F@EE*$K3NJ]5l$k!%$3$N0UL#$GEvelyn $N%U%!%s%/%7%g%s$O$`$7$mVHDL $N
%3%s%]!<%M%s%HJI$K6a$$$bNG$"$k!%

%U%!%s%/%7%g%s$O<B9T;~$KA4$FE83+$5$l!$$l DN<B9T%f%K%C%H$NM-8~%0%i%U
$,:n$ilk!%%U%!%s%/%7%g%s8F$S=P$7HO!$$=lKhC$F?7$?$K%G!<%?NN0h$,
3NJ]5lkh$&$JbNGOJ/!$>o$KB8:_7F$$k1 DN%U%!%s%/%7%g%sNN0h
KBP7$F%G!<%?rEO$9$3$H$G<B8=$5lkbNG"$k!%

5 F0:n5-=R

K\>OGO6qBNE*$JF0:n5-=RJ}K!$r@bL@9k!%

5.1 %b%8%e!<%kIt

%b%8%e!<%k$O%b%8%e!<%kIt$GDj5A9k!%%b%8%e!<%kIt$NLr3d$O!$%U%!%s%/%7%g
%s!$FbItJQ?t$JIN@k8@$HFbIt%b%8%e!<%k$N%3%s%U%#.%e&l!<%7%g%sG"$k!%

```
x1 << 0;                                  (1)
x2 << 1;                                  (2)
( y1, y2 )func( x1, x2 );                 (3)
z << y1 + 1;                              (4)
```

?^14: %U%!%s%/%7%g%s8F$S=P$7

?^13$K%b%8%e!<%kIt$N9=@.$r<($9!%?^Nh$&$K%b%8%e!<%kIt$Ogeneric It!$private It!$public It!$configuration It!$$=7Fport It$+$iJk!%3liNLr3d$OOJ2<$K=RYkDLjG$"$k!%

generic It %3%s%Q%$%k;~$KM?$($ilkJQ?t$r@k8@$9$k!%

private It %b%8%e!<%k$K%m!<%+%k$JJQ?t/%U%!%s%/%7%g%s$N@k8@!$5Z$SFbIt%b%8%e!<%k$N%$%s%9%?%s%9@8@.$r9TJ&!%

public It %b%8%e!<%k30It$+$i$b%"%/%;%9$G$-$kJQ?t/%U%!%s%/%7%g%s$N@k8@$r9TJ&!%

configuration It FbIt%b%8%e!<%kF1;N$N@\B3$rDj5A9k!%

port It 30It%b%8%e!<%k$HDL?.$9k?aN%]!<%H(8e=R)$rDj5A$9$k!%

5.2 %U%!%s%/%7%g%s

5.2.1 %U%!%s%/%7%g%s

%U%!%s%/%7%g%s$N30It%$%s?%U%'!<%9$NDj5A$O%b%8%e!<%kIt$Nprivate It$+public It$G9T$J$&!%0J2<$K%U%!%s%/%7%g%sDj5A$N%U%)!<%^%C%H$r<($9!%

```
( JVCM%j%9%H ) %U%!%s%/%7%g%s<1JL;R[G[Ns%5%$%:]( 0z?t%j%9%H );
```

%U%!%s%/%7%g%s$OJ#?t$N0z?t/JVCM$r;}$D3H$,$G$-$k!%2>0z?t%j%9%H$H2>JVCM%j%9%H$KF1$8L>A0$NbN$,B8:_$7$?$i!$$=lO;2>H8F$S(*call by reference*)$G$"$k!%$=$l0J30NbNOA4$FCM8F$S(*call by value*)G"$k!%

%U%!%s%/%7%g%s$OG[Ns$H7FDj5A9k3HbG$-$k!%G[NsH7$FDj5A$7?$$>19gKO!$@k8@;~$KG[Ns%5%$%:$rM?$($k!%G[Ns%5%$%:$O%3%s%Q%$%k;~$K7hDjG-kbNGJ1lPJi$J$$!%>\$7$/$O5.2.2@a$G@bL@$9$k!%

?^14$K%U%!%s%/%7%g%s8F$S=P7NNc$r<($9!%0z?t x1!$x2 NCMr(1)(2)$G@8@.$7!(3)G%U%!%s%/%7%g%sfunc $r8F$S=P$9!%

3NNcGOx1!$x2 Hb$Ksingal$G$"$kNG!$(1)(2)$N<B9T$,%V%m%C%/$9kH8eB3L?Na$N<B9T$b%V%m%C%/9k!%$=$N>19g!$%V%m%C%/9kOLCV$O(3)$N%U%!%s

%/%7%g&s8F$S=P$70LCVGOJ/!$%U%!%s%/%7%g&sfunc FbIt$Gx1!$x2 NCMr;2
>H9k0LCVG"$k!%$D$^$j%U%!%s%/%7%g&s$r8F$S=P9H$-$K0z?t$,A4$FB7GF
$$$kI,MWOJ$$!%

F1MM$KJVCM$b=`HwNG$-$?bN$+$iJV5l$k!%$3NNcG$Oy2 $,JV$5lJ$/$F
$by1 $,JV$CF-$?;~E@$G(4) $r<B9T$7F7$^$&!%

J*%U%!%s%/%7%g&s8F$S=P$7;~$K0z?t$rB7$($F$*$/I,MW$,$J$$$+iH$$$C$F!$
Nc$($P(1) $r(3) $N8e$K0\F0$9$kh&J3Hr7FOJiJ$$!%3l$O!$Evelyn
GO%W%m%0%i%`!&*!<%@KhCF0MB84X78$rH=Dj$9k?aG$"$k!%

H3mG!$<B0z?t$+$i2>0z?t$XNCMN<u$1EO$7$OBeF~$GOJ$/f%K%U%#%1!<
%7%g&sG"$k!%0z?t$N<u$1EO$7Kh$j9%F!<%8$,6h@Zilk3HO$J$$!%

$^$?JVCMXNBeF~$O!$%U%!%s%/%7%g&sFbIt$G9T$Jol$k2>JVCM$X$NBeF~$,??
$NBeF~$G$"$k!%2>JVCM$+$i<BJVCMXNCM$N<u$1EO7Of%K%U%#%1!<%7%g&sG"$C
$FBeF~$GOJ$$!%=>CF!$$3$3$G%9%F!<%8$,6h@Z$ilk3HOJ$$!%

5.2.2 %U%!%s%/%7%g&s$NG[Ns

Evelyn $N%U%!%s%/%7%g&s$O!$C JI$N4X?t$Nh&$K8F$S=P$7Kh$KF0E*$K%$s
%9%?%s%9$,@8@.$5lkh&JbNGOJ$$!%%U%!%s%/%7%g&sKh$K1 DN%$s%9
%?%s%9$,@EE*$K@8@.5l$k!%

F10l$N%U%!%s%/%7%g&s$N%$s%9%?%s%9$rJ#?t@8@.7?$>19g$K$O%U%!%s%/%7%g
%s$rG[Ns$H7F@k8@9k!%G[Ns%$%s%G%C%/%9$,0c$&%U%!%s%/%7%g&s$OJL$N%$s
%9%?%s%9$,@8@.$5lk!%

%U%!%s%/%7%g&s$O@EE*$K@8@.5l$k%$%s%9%?%s%9JN$G!$G[Ns%5%$%:$O@EE*
$K7hDj$9kbNGJ1lPJi$J$$!%

5.2.3 @)Ls%U%!%s%/%7%g&s

F1;~$KH/9T$5lkJ#?t$N%U%!%s%/%7%g&s8F$S=P7rE}0lE*$K=hM}$7$?$>19g
KO!$=hM}$r@)Ls%U%!%s%/%7%g&s$rMQ$$$F5-=R9k!%

?^15$K@)Ls%U%!%s%/%7%g&s$N5-=RNc$r<($9!%^$O%"!<%S%H%l!<%7%g&s2sO)$G!$
NUM 8D$N%b%8%e!<%k$+$i%j%/(%9%H$r<u1k$H%H!<%/%s!&j%s0J}<0$Khj
%"!<%S%H%l!<%7%g&s$r9T$J$&!%

$^$:!$%b%8%e!<%kIt$Npublic It$G%"!<%S%H%l!<%7%g&s=hM}$r9TJ&%U%!%s%/
%7%g&srequest $r@k8@$9$k!%%U%!%s%/%7%g&srequest $O!$F1;~$K<u$1$?%j%/(%9
%H$rE}0lE*$K=hM}7J1lPJiJ$$$?a!$@)Ls%U%!%s%/%7%g&s$H7F@k8@$9
$k!%%U%!%s%/%7%g&srequest $O!$NUM 8D$NG[Ns$H7F@k8@9k!%G[Ns%$%s%G%C

```
module arbitor{
    generic:
        const int NUM;
    private:
        singal int owner;
    public:
        restricted (singal boolean grant[NUM])request[NUM]();
}
// ------------------------------------
restricted(singal boolean grant[NUM])request(){
    signal int i;
    signal int idx;
    signal boolean flag;

    flag <= false;
    for ( i <= 0; i < NUM; i++ ){
        idx <= (OWNER+1+i) % NUM;
        if ( (port[idx] in CALLER) ){
            if ( flag == false ){
                grant[idx] << true;
                owner << idx;
                flag <= true;
            }
            else{
                grant[idx] << false;
            }
        }
    }
}
```

```
?^15: @)Ls%U% !%s%/%7%g%s$NNc
```

%/%9Kh$jcaller $rFCDj$9k?aG$"$k!%

%3%a%s%H9T0J9_$,@)Ls%U%!%s%/%7%g%srequest $NFbMF$G$"$k!%?^Cf!$*CALLER*
HOFCJL$JJQ?t$G!$Ev3:%5%$%/%k$G8F$S=P5l$?@)Ls%U%!%s%/%7%g%s$NG[Ns%$
%s%G%C%/%9$,3JG<$5lF$$kbNG"$k!%%U%!%s%/%7%g%srequest KC0J2<$N
h&$J%k!<%k$K=>CFF0:n9kh&$K5-=R$5lF$$k!%

- OWNER $K5-O?$5l?8=:_$N%*!<%J$NNY$N%b%8%e!<%k$+$i=g$KD4YF$$$-!$
  $=$N%5%$%/%k$G%j%/%(%9%H$rH/9T$7$F$$$k:G=i$N%b%8%e!<%k$K%0%i%s%H$r
  M?$($k(grant = true rJV9)!%
- $=$l0J30$N%j%/%(%9%H$rH/9T7F$$k%b%8%e!<%kKBP7FO%0%i%s%H$,F@
  ilJ+C?3HrEA$($k(grant = false rJV9)!%
- %j%/%(%9%H$rH/9T$7$F$$J$$%b%8%e!<%kKBP7FO2?b7$J$$!%

5.3 30It%b%8%e!<%kHNDL?.

A0Kb=RY?DL$jEvelyn GODL?.$r%U%!%s%/%7%g%s8F$S=P7KCj>]2=9k!%
30It%b%8%e!<%kKBP7$FDL?.$r9TJ&>l9g$b4pK\E*$KF1$8$G$"$k$,!$1 $DLdBj
$,@8$8$k!%$=lO!$30It$NDL?.Aj<j$rM[$K5-=R7F7^$&$H!$@_7W$N%]!<%?%S
%j%F%#$,BgI}$KB;JolF7^$&$3HG$"$k!%

$=$3$G!$%]!<%H$H$$&bN$rMQ$$$F30It$N%b%8%e!<%k$HDL?.9k!%%]!<%H$,
30It%b%8%e!<%kHNDL?.$rCg2p$9$k!%

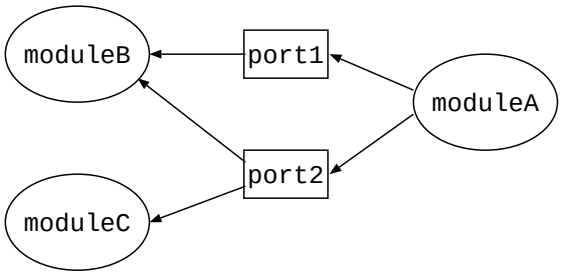
30It%b%8%e!<%kHNDL?.$,I,MW$J%b%8%e!<%kKO%]!<%H$rMQ0U$9$k!%$=7F
>e0L%b%8%e!<%kG=$N%b%8%e!<%k$r%$%s%9%?%s%92=$9$k:]$K!$%]!<%H$rDL?.Aj
<j$H@\B3$9$k!%

1 DN%b%8%e!<%kOG0U8D$N%]!<%H$r;}D3H,G-!$$^$?1 DN%]!<%HG
0U8D$N%b%8%e!<%k$K@\B3$9$k3H$,$G$-$k!%=>CF!$J#?t$N%b%8%e!<%k$r2>A[
E*$K1 DN%b%8%e!<%kH_J7$?$j!$5U$K1 DN%b%8%e!<%k$rJ#?t$N%b%8%e!<
%kH_J9$3$HbG$-$k!%

D^$j?^16$N%h$&$K!$port2 rDL7$FmoduleB($N0lIt) $HmoduleC ($N0lIt)
$r1 DN%b%8%e!<%kH7F_J7$?$j!$moduleB $rport1 $Hport2 rDL7$FJL!9
$N%b%8%e!<%k$H$_$J$9$3H,G-$k!%

%b%8%e!<%kItG=$N%b%8%e!<%k$,;}$D%]!<%H$NDj5A$r9T$J$&!%$3$3$G%]!<%H
$NDj5A$H$O!$

- %]!<%H$NL>A0



?^16: %]!<%H$r2p$7$?DL?.

```
module A{
    private:
        ( signal int i )send();
    port:
        port0( (signal float a)send() );
};
```

?^17: %]!<%H$N@k8@

- $=$N%]!<%H$r2p$7$F%"%/%;%9$9$k%U%!%s%/%7%g%s$N%j%9%H $rDj5A$9k3HG$"$k!%

?^17$O%]!<%H$NDj5A$r4^$`%b%8%e!<%kItNNcG$"$k!%module A $Oport0 $r2p$7$F30It%b%8%e!<%k$Nsend $H$$$&%U%!%s%/%7%g%s$K%"%/%;%9$9$k!%

%]!<%HF1;N$N@\B3$O!$>e0L%b%8%e!<%k$G$=$N%b%8%e!<%k$N%$%s%9%?%s%9$r@8@.$9kH$-$K9TJ&!%?^18$O!$?^17$GDj5A$7$?%b%8%e!<%k A $rFbIt$K;}$D%b%8%e!<%k C $N%b%8%e!<%kIt$G$"$k!%$^$:private It$GC $,;}$DFbIt%b%8%e!<%k the_A $Hthe_B $r@k8@$9$k!%$=7F!$configuration It$G!$?^17$Gextern $H@k8@$7$?%U%!%s%/%7%g%ssend $r%b%8%e!<%kthe_B $Nsend G"kHDj5A9k!%

5.4 singal

K\@aGO!$singal $rMQ$$$EMM!9$J5-219=B$$r5-=R9kJ}K!$r=R$Y$k!%

5.4.1 F14|J}K!$N;XDj

Evelyn GO!$singal $r5-21%W%j%_%F%#%V$H7FDs6!7F$$$k!%singal OFI_=q$-$,F1;~KG$-$k9b5!G=JbNG$"$k!%7+$7!$9bB.@-hj$b%O!<%I%&%"

```
module C{
    private:
        A the_A;
        B the_B;
    configuration:
        the_A[]{
            port0( send → the_B.port1.send );
        };
    port:
}
```

?^18: %]!<%HF1;N$N@\B3

NL$rM%@h$7$?$$H$-$J$I!$$h$j%7%s%W%k$JbN$,M_$7$$>l9g$,$"$k!%

$=$Nh&$J>l9g$O!$singal rAH_9go;$FL\E*$N2sO)$rI=8=9k!%singal $rMQ $$FI=8=9k$H$$&3H$G!$$h$jJ#;($J2sO)$,9g@.$5lkNGOH9M$($kFI<T $b$$$k$+$b7l$J$$$,!$5!G=9g@.7O$,@5$7$/9g@.9kNGLdBj$J$$!%

singal HO4pK\E*KFI_=P7H=q$-9~$_$,F1;~$KG-kbNG$"$k!%b7FI $_=P$7$H=q$-9~$_$,F1;~KG$-$J$$$h$&$K7?$$>l9gKO!$@_7W<T$,singal $rMQ$$F$=$Nh&$J5-21$rDj5A9k!%

?^19$O!$F1;~KFI_=q$-$NG-$J$$5-21(%b%8%e!<%ksequential_singal)$NDj 5ANc$G$"$k!%b%8%e!<%ksequential_singal $Owrite(=q$-9~$_)!$read(FI$_=P$7) $N2 DN%U%!%s%/%7%g%s$r;}$D!%&3l$i2 DN%U%!%s%/%7%g%s$rMQ$$F!$<B:] KCMrJ];}9kJQ?t_core $K%"%/%;%9$k!%

%U%!%s%/%7%g%swrite GO!$1i;;R?$rMQ$$F$$k!%?$OEvelyn KAH_9~$_$N 1i;;R$G!$singal $KM-8z$JCM$,J];}$5lF$$k>l9g$O?$?rJV9!%$^$?!$NOLCV$K hj%9%F!<%8$,J,3d$5lk!%

while %k!<%WKh$j!$_core $,M-8z$JCM$r;}$G$F$$k4VBT$AB3$1!$_core $,M-8z JCMr<:JC$?;~E@$G7$?JCMr=q$-9~$`!%

%U%!%s%/%7%g%sread $O!$write HOFHN)$K_core NCMrFI$_=P$9!%

3Nh&$K5-=R$9lP!$F1;~$KFI$_=q$-NG$-$J$$sequential singal $rDj5A 9k3H,G-$k!%singal N_$r;H$&>l9gKHfY$F5-=RNL$,A}$($k$?$a!$J#;($J2sO)$,9g@.$5lF7^$&$h$&$K$_$(k,!$5!G=/O@M}9g@.7O$,E,@Z$K9g@.$9$k

```
module sequential_singal{
    private:
        singal int _core;
    public:
        (signal int data)read();
        ()write(signal int data);
}
()sequential_singal::write(data){
    while( ?_core ){
        NULL;
    }   _core << data;
}
(singal int data)sequential_singal::read(){
    data << _core;
}
```

?^19: F1;~KFI_=o$-$G$-$J$$5-21

NGLdB j$J$$!%

5.4.2 %a%b% j$N5-=R

Evelyn $G%a%b% j$r5-=R9kJ}K!$r=R$Y$k!%

Evelyn $G%a%b% j$rI=8=9kKO5-21%W% j%_%F%#%VH7$Fsignal $rMQ$$$k!%3l$O!$%a%b% j$N!$$"$k%"%I%l%9$NFCD jNCMr;2>H9k2s?t$r@EE*$KFCD j9k3H$,0lHL$KIT2DG=G"k+iG$"$k!%

signal $NG[Ns$G!$8e$K=RYk>r7o$rK~$?9bNO%a%b% jH7$F5!G=9g@.$5lk!%

signal $OF14|5!9=$r;}$?$J$$$?a!$F14|$N$?$a$N2sO)$O?M< j$G5-=R$7J/FOJi$J$$$!%9JoA!$J#?t2U=j$+$i%"%/%;%9$5lk2DG=@-$,$"$k>19g$K$OGSB>@)8f$N$?$a$N2sO)$r5-=R9kI,MW$,$"$k!%singal Kh$j%a%b% j%"%I%l%9%l%8%9%?$d%a%b% j%G!<%?%1%8%9%?$r5-=R$9k3HKJk$@m&!%

5F!$signal $NG[Ns$r%a%b% j/%1%8%9%?%U%!%$%k$H7F9g@.9kKO!$F10l%5%$%/%k$G1$D$J$$$72DNFCD j$NG[NsMWAG$K7+%"%/%;%9$5$l$J$$I,MW$,$"$k!%

3N$?$a$N==J,>r7o$O!$

- @)Ls%U%!%s%/%7%g%s$GJ]8n$5lF$$$k$+!$1DJ$$72DN%]!<%H$r2p$7$F%"%/%;%9$5lk%U%!%s%/%7%g%s$+$iN_%"%/%;%9$5$l$k!%
- $=$liN%U%!%s%/%7%g%sFb$GF10l%5%$%/%k$G1$D$J$$72DNG[NsMWAGK7$+%"%/%;%9$5lJ$$!%

3HG"$k!%

5!G=9g@.7O$O!$%a%b% jH7$F<B8=$9kH$$$&9g@.%G%#%l%/%F%#%V$rM?$(il$?signal $NG[Ns$G!$$3$N>r7o$rK~$?$9bN$r%a%b% j$H7F5!G=9g@.9k!%

5.5 5-=RNc

A0@a$^$G$KEvelyn K*1kF0:n5-=RJ}K!KD$$$F=RY?!%K\@aGOEvelyn $N6qBNE*$J5-=RNc$r<($9!%

$3$3GOF0:n5-=RNcH7$FIBM 360/91 $N1i;;AuCV$N5-=R9k!%IBM 360/91 $N1i;;AuCV$OTomasulo $N%"%k%4%j%:%\$Khj1i;;$rOut-of-Order <B9T$7$F$$$k!%

$^$:?^20$O!$1i;;AuCVA4BN(alu)$KBP1~$9$k%b%8%e!<%kIt$N@k8@G"$k!%generic It$GDj?t$r@k8@$7!$private It$GFbIt%b%8%e!<%k$r@k8@$7$F$$$k!%FbIt%b%8%e!<%k$N@k8@$G$O!$generic It$G<u$1HC$?Dj?t$r;HCF$$$k!%3li$NDj?t$O!$Fb It%b%8%e!<%k$Ngeneric Dj?tHJ$k!%

```
module alu{
    generic:
        const int FL_SIZE; // IbF0>.?tE@L?Na%9%?%C%/
            ⋮
    private:
        flos the_flos( FL_SIZE ); // IbF0>.?tE@L?Na%9%?%C%/
        flr the_flr( FLR_SIZE ); // IbF0>.?tE@%l%8%9%?
            ⋮
    public:
        () set();
        () add( singal tag_t dtag, singal float src1, singal float src2 );
        () mul( singal tag_t dtag, singal float src1, singal float src2 );
};
```

?^20: Tomasulo $N%"%k%4%j%:%`:%b%8%e!<%kIt

$^$?public It$G0J2<$N3 DN%U%!%s%/%7%g%s$r@k8@$7$F$$$k!%

set %G%3!<%I7?L?Na$r%j%6%Y!<%7%g%s!&9%F!<%7%g%s$K=q$-9~$`!%

add <B9T2DG=$JL?Na$r%j%6%Y!<%7%g%s!&9%F!<%7%g%s$+$i<h$j=P$7$F2C;;$r <B9T9k!%

mul <B9T2DG=$JL?Na$r%j%6%Y!<%7%g%s!&9%F!<%7%g%s$+$i<h$j=P$7$F>h;;$r <B9T9k!%

<!$K?^21$K1i;;AuCV(alu) $N%U%!%s%/%7%g%s$N1 $D!$set $NH4?h$r<($9!%$3$N %U%!%s%/%7%g%s$K$Oalu $NF0:n$NA0H>It!$$9Jo$A%G%3!<%I$7$?L?Na$r%j%6%Y!< %7%g%s!&9%F!<%7%g%s$K%;%C%H$9k^GNF0:n$r5-=R$7$F$$$k!%

%U%!%s%/%7%g%sKO!$(1) IbF0>.?tE@L?Na%9%?%C%/(the_flos) $+$i%G%3!<%I:Q $_$NL?Na$r<h$j=P$7!$(2) IbF0>.?tE@%l%8%9%?(the_flr) $+$i%*%Z%i%s%IrFI_ =P$7!$(3) 2C(>h);;4dMQ%j%6%Y!<%7%g%s!&9%F!<%7%g%s(the_a(m)rsvst) $K=q$- 9~$_!$(4) :G8e$K%j%6%Y!<%7%g%s!&9%F!<%7%g%s$N%(%s%H%j$N%?%0$rthe_flr $K =q$-9~$`!$$H$$$&0lO"$N=hM}$r$=$N$^$^5-=R7F$$$k!%

3Nh&$J5-=R$OEvelyn Kh$k%O!<%I%&%'%"5-=R$NFCD'rh$/I=$7$F$$$k!% Evelyn GO$^$:?^21Nh$&$KF0:n$r5-=R$7!$$=$N8e$G%9%F!<%86-3&H7$?$$JQ ?t$rsingal $KJQ99$9kNG"$k!%

```
() alu::set(){
                :
    /* IbF0>.?tE@L?Na%9%?%C%/(FLOS) $+$iL?Na$r<h$j=P$9*/
    ( inst, dreg, lreg, rreg )the_flos.get();

    /* IbF0>.?tE@%l%8%9%?(FLR) $+$i%*%Z%i%s%I$rFI$_=P$9*/
    ( lbusy, ltag, ldata )the_flr.read( lreg );
    ( rbusy, rtag, rdata )the_flr.read( rreg );

    /* %j%6%Y!<%7%g%s!&9%F!<%7%g%s$X$N=q$-9~$_*/
    if ( inst == ADD ){ /* the_arsvst : 2C;;4cMQ%j%6%Y!<%7%g%s!&9%F!<%7%g%s*/
        (dtag)the_arsvst.put(ltag,ldata,rtag,rdata);
    }
    elsif ( inst == MUL ){
                :
    }
    /* FLR $N%?%0!$%S%8!<%S%C%H$r%;%C%H$9$k*/
    ()the_flr.setbusy( dreg, dtag );
}
```

?^21: %G%3!<%I7?L?Na$r%j%6%Y!<%7%g%s!&9%F!<%7%g%s$K%;%C%H$9$k%U%!%s%/%7%g%s(H4?h)

```
( singal int tag )rsvst::put
            ( singal int ltag, rtag, singal float ldata, rdata )
{
    signal int i;
    singal boolean success << false;

    while ( !success ){ /* A0$N%5%$%/%k$G=q$-9~$a$J$+$C$?$i */

        success << false;
        for ( i <= 0; i < SIZE; i++ ){ /* A4$F$N%(%s%H%j$rC5$7$F */
            if ( rs_entries[i].vld == false ){ /* 6u$-%(%s%H%j$r8+$D$1$?$i */
                rs_entries[i].set( ltag, ldata, rtag, rdata, true );
                tag << i;
                success << true;
            }
        }
    }
}
```

?^22: %j%6%Y!<%7%g%s!&9%F!<%7%g%sXN=q$-9~$_

?^22$K< ($7$?%U%!%s%/%7%g%sput $O!$%j%6%Y!<%7%g%s!&9%F!<%7%g%s(rsvst) $,; }$D%U%!%s%/%7%g%s$Nl DG$"$k!%%U%!%s%/%7%g%sput $NLr3d$O!$%j%6%Y!<%7%g%s!&9%F!<%7%g%s$N6u$-% (%s%H%j$K%*%Z%i%s%I$r=q$-9~$_!$$=$N% (%s%H%j$N%?%0rJV9$H$$$&bNG"$k!%

3N%U%!%s%/%7%g%sput $O!$singal $N@-<A$rMxMQ7?Evelyn FHFC$N5-=R$HJG$F$$k!%%]%$%s%H$O%j%6%Y!<%7%g%s!&9%F%$%7%g%s$K6u$-% (%s%H%j$,$J$$$H$-$N=hM}G"$k6u$-% (%s%H%j$,$J$$>l9gKO!$$=3G<B9T$r%V%m%C%/$7$F%j%6%Y!<%7%g%s!&9%F!<%7%g%s$,6u$/NrBT$?$MPJiJ$$!%%U%!%s%/%7%g%sput GO3l$rsingal $rMQ$$$F9*$_$K<B8=7F$$k!%

?^Cffor %k!<%WGO%j%6%Y!<%7%g%s!&9%F!<%7%g%sCf$N% (%s%H%j$r=g$KD4$Y$F$$-!$6u$-% (%s%H%jr_D1$?$i=3K%G!<%?$r=q$-9~$'$H$$&=hM}r7$F$$k!%3N=hM}$rwhile %k!<%W$G7+jJV7<B9T9k3H$G!$% (%s%H%j$,6u$/NrBTCF$$kLuG"$k!%

3Nwhile %k!<%W$N>r7o$HJC$F$$$ksingal success $,5-=R$N4NG"$k!%success $rsingal $G<B8=$7!$while %k!<%W$N3F%$%?%l!<%7%g%s$GI,$:success $KBeF~$9kh$&$K7F$$k3H$G!$while %k!<%W$N%$%?%l!<%7%g%s$r1 %5%$%/%k$G<B9T$9kh$&$K5-=R7F$$kNG$"$k!%

9k$H!$

- %5%$%/%kKh$Kfor %k!<%W$,1 2s<B9T$5lk!%
- while %k!<%W$rH4$1k^GOput $N0z?t(A4$Fsingal) $K%"%/%;%9$7B3$1$k!%

$?$a$K!$put $N0z?t$Nsingal N?aK!$8eB3%G!<%?$N<B9T,%V%m%C%/5lkNG"$k!%

5.6 F0:n5-=RN^Ha

0J>e!$Evelyn $NF0:n5-=RJ}K!$K$D$$F=RY?!%

Evelyn $O=>Mh$N5!G=%l%Y%kHDL HC0[Jj!$%O!<%I%&%'%"$rF0:nC10L$K5-=R$7!$$=3Khj>\:Y$J@_7W>pJs$rIU2C7F$$/$H$$&%"%W%m!<%A$r:N$k!%$=$N$?a!$F0:n5-=R$NCJ3,$G$OF0:n@_7W$N$_$K@l?4G-$k!%

F0:n@_7WCJ3,$G5!G=%l%Y%k$N@_7W>pJsrI,MWH7J$$$?a!$F0:n$N5-=R/JQ99$OMF0W$K9TJ(%k!%$=$N$?a!$7>O$G=R$Y$kF0:n%7_%e&l!<%?$HAH$_9g$o$;$F;H$($P!$3+H/A0$N@-G=I>2A$dF0:n%l%Y%k@_7W8!>Z$r8zN(h/9TJ&3H$,$G$-$k$?$a!$J}<0@_7W$N8eH>$+$iMxMQ9k3H$,$G$-$k!%7+$bEvelyn $NF0:n5-=R$r

$=$N8e$N@_7W9)Dx$G$=$N$^$^MxMQG-k3Hr9M$($l$P!$=>Mh!$C 8@8l$JIG
9TJolF$$?%7%_%e%l!<%7%g%s$rEvelyn KCV-49$(ilkH9M$(il$k!%
<!>OGO3Nh&$J5-=R$,LdBjJ/%7%_%e%l!<%7%g%s!$5!G=9g@.$,G-kH
$$$&3H$r<($9!%

6 5!G=9g@.

0J>e!$Evelyn Kh$j%H%C%W%@%&%s$K%O!<%I%&%'%"$r5-=RG-$k3H$r=RYF
$-$?!%0J2<K\9FGO3NEvelyn 5-=R$N%7%_%e%l!<%7%g%s/5!G=9g@.<jK!KD$$
$F=R$Y$k!%

$^$:K\>O$GEvelyn $N5!G=9g@.[1]<jK!$K$D$$F=RYk!%0J2<5!G=9g@.$NN.$l$K
$D$$F=RY?8e!$C10l%U%!%s%/%7%g%s$K8BC?5!G=9g@.KD$$F@bL@$7!$%U%!
%s%/%7%g%s4VGN;q8;6&M-JI%b%8%e!<%kA4BN$N5!G=9g@.$K$D$$F@bL@9k!%

6.1 5!G=9g@.$N35MW

6.1.1 5!G=9g@.7O

Evelyn Kh$kF0:n@_7W5-=R$O!$5!G=9g@.7O$Khj5!G=@_7W5-=R$K<+F09g@.$5
lk!%5!G=9g@.7O$O!$F0:n5-=R$H<!@a$G=RYk9g@.%G%#%l%/%F%#%V$rF~NO$H$7
$F<u$1$F!$VHDL Kh$k5!G=@_7W5-=R$r=PNO9k!%

5!G=%l%Y%k5-=RH7$FVHDL 5-=R$r9g@.9kM}M3$O!$$=$N8e$NO@M}%7%_%e
%l!<%7%g%s!$O@M}9g@./:GE,2=9)Dx$K9-$/N.DL$7$F$$kM%l?%D!<%k$r;H$&3H
$,$G$-$k$H$$&E@N_G"$k!%=$Nh&$J%D!<%k$r;H$&$3$HGEvelyn r9$0$K
<B:]$N%O!<%I%&%'%"@_7W$KMxMQ2DG=H9k3HrA@CF$$k!%

6.1.2 9g@.%G%#%l%/%F%#%V

@_7W>pJsN&$A!$F0:n$K@-G=0J30$NE@$G1F6A$r5Z$\$5$J$$h$&$JbN$O!$9g
@.%G%#%l%/%F%#%VH7$FM?$($k!%3$Nh&K9k3HG!$J*M}E*@)Ls$rK~$?$9
$?$a$K@_7WUQ99$,I,MWKJC?>l9gGb!$F0:n5-=R$KA4$/1F6A$rM?$($k3H$J
$/@_7WUQ99$r9TJ&3H$,$G$-$k!%

3N9g@.%G%#%l%/%F%#%V$O!$C1$K9g@.;~$N%*%W%7%g%sH7$FM?$(kNGO$J
$/!$$8@8l;EMM$N0lIt$H7F5,Dj9k!%8@8l;EMMH7$F5,Dj$7!$$=$N%;%^%s%F%#
%/%9$rL@3N$K9k3H$G!$5-=R$N0UL#$,=hM}7OOMB8$K0MB8$9kh$&$J3H$,5/

[1] F0:n9g@.$HI=8=$5lk3H$,$"$k!$$8mMQG"$k!%5!G=%l%Y%k5-=R$r9g@.9kN@+$i5!G=9g@.$HI=8=9Y$-$G$"$k!%

enum beatle(john, paul, george, ringo)
map to bit_vector("00","01","10", "11");

?^23: Ns5s7?$N%S%C%HNs$X$N%^%C%T%s%0

singal int data *range 0 to 255*;

?^24: %G!<%?$NHCOO$N;XDj

iJ$$h$&$K9k!%3Nh&K9lP5-=R$N%]!<%?%S%j%F%#$,9b$^$j!$@_7W<T$,=hM}7ONUJKG:$^$5lk3H$,$J$/$J$k!%

9g@.%G%#%l%/%F%#%VNNcr<($9!%

Evelyn $G;HMQ$G$-$kCj>]7?$O!$5!G=9g@.;~$K9g@.%G%#%l%/%F%#%V$rM?$($k3H$G>\:Y2=$9k3H,G-$k!%6qBNE*$K$OOJ2<$Nh&$J%G%#%l%/%F%#%V$rM?$($k3H$,$G$-$k!%

- boolean 7?$N'0'!$'1'XN%^%C%T%s%0!%O@M}$r@5O@M}!$IiO@M}NIAi$G<B8=$9k+A*Br9k!%
- Ns5s7?$N%S%C%HNs$JIX$N%^%C%T%s%0!%
- %G!<%?$N%S%C%HI}$N;XDj!%

$?$@$7VHDL GbNs5s7?$r;H$&3H$,G-$kNG!$A4FNUQ?t/7?KD$$$F>\:Y2=$r9T$J$&I,MW$O$J$$!%@_7W>e%/%j%F%#%+%k$J>l9g$d%A%C%W$N30It%T%s$JIG;EMM$,M=$aDjailF$$k>l9g!$$=7F%W%m%0%i%`$NOUL#$r5!3#E*KFI_HkN,:FqGO@M}9g@.7O$,E*3N$K=hM}G-$J$$H9M$($ilk>l9gN_9TJ(Ph$$!%

Ns5s7?(boolean $r4^$`)$N%S%C%HNs$X$N%^%C%T%s%0$O?^23Nh$&$K9$k!%?^Cf!$%$%?%j%C%/BN$N5-=R$,9g@.%G%#%l%/%F%#%V$G$"$k!%F0:n5-=R$K*$$F$=$NNs5s7?$rDj5A$7F$$k2U=j$K!$$3lrVHDL $Nbit_vector 7?$K%^%C%T%s%0$9$k$H$$&0UL#$N9g@.%G%#%l%/%F%#%V$rM?$($k!%

0lJ}!$%G!<%?%S%C%HI}$N;XDj$O?^24$Nh&$K9T$J$&!%$3lb?^23$HF1MM!$%$%?%j%C%/BN$N5-=R$O9g@.%G%#%l%/%F%#%V$G$"$k!%JQ?t$N@k8@2U=j$K%S%C%HI}$r;XDj$9$k%G%#%l%/%F%#%V$rM?$($k!%

GO6qBNE*$J5!G=9g@.J}K!$r@bL@9k!%

```
module A{
    private:
        ()funcA(
            addr map to bus : bit_vector( 35 downto 0 ),
            data0 map to bus : bit_vector( 63 downto 0 ),
            data1 map to bus : bit_vector( 63 downto 0 )
        );
}
```

?^25: entity port XN%^%C%T%s%0

6.2 %b%8%e!<%k$N5!G=9g@.

K\@aGO%b%8%e!<%k$N5!G=9g@.<jK!$r@bL@9k!%%b%8%e!<%k$N5!G=9g@.$G$O!$J#?t%U%!%s%/%7%g%s4VGN;q8;6&M-$,Bg$-$J%F!<%^$HJk!%

6.2.1 %U%!%s%/%7%g%s$N%(%s%3!<%G%#%s%0

Evelyn GO%b%8%e!<%k4VDL?.$r%U%!%s%/%7%g%s8F$S=P7KCj>]2=7F$$k$,!$5!G=9g@.9k:]KO!$$3lrO@M}?.9f$K>\:Y2=$9kI,MW,$"$k!%

9JoA%U%!%s%/%7%g%s$r8F$S=P9H$$&3H$K4^$^lk>pJs(0J2<GO%3%^%s%I$H8F$V)$,$"$k!%<B:]$N%O!<%I%&%'%"GO3l$O?.9f@~$H7F<B8=5l$k!%5!G=9g@.$9$k:]$K<B8=J}K!$r;XDj$7J1lPJi$J$$!%

5i$K!$;~4VE*$KI}$r;}CFdjHj5l$k%U%!%s%/%7%g%s$N0z?t/JVCM$r!$E,@Z$J?.9f@~$K%^%C%T%s%0$9$kI,MWb"$k!%

%^%C%T%s%0$N;XDj$O!$6.1.2@a$G=RY?h&$K>\:Y2=$7$?%G!<%?$r!$VHDL $NJ8K!$G5-=R7?*entity port* $K%^%C%T%s%0$9k3HG9TJ&!%

?^25$O6qBNNc$G$"$k!%?^Cf%$%?%j%C%/BN$G5-=R7?bN$,9g@.%G%#%l%/%F%#%V$G$"$k!%3NNc$O!$funcA $H$$&%U%!%s%/%7%g%s $r;}$D%b%8%e!<%kA $K9g@.%G%#%l%/%F%#%V$rIU2C7?bNG"$k!%

funcA $N@k8@It$G!$addr $rbit_vector 7?$N*bus* $N35!A0%S%C%HL\$K%^%C%T%s%0$7!$data0 $Hdata1 $r*bus* $N63!A0%S%C%HL\$K%^%C%T%s%0$9$kh&$K%G%#%l%/%F%#%V$rM?$($F$$k!%

3NNcGO!$%b%8%e!<%kA $O1 DN%U%!%s%/%7%g%s7+;}$?$J$$?$a!$%3%^

%s%I$N%(%s%3!<%G%#%s%0$OEP>l7F$$$J$$$,!$%3%^%s%I$N%(%s%3!<%G%#%s%0$b
F1MM$K9T$J$&!%$9Jo$A%b%8%e!<%k$,;}$D%U%!%s%/%7%g%s$r0l<o$NNs5s7?$H$_
J7$F!$6.1.2@a$G=R$Y$?$h$&$K%S%C%HNs$K%^%C%T%s%0$9$k!%$=7F5iK3$N
%S%C%HNs$r?.9f@~$K%^%C%T%s%0$9$k!%

6.2.2 ;q8;6&M-

2sO)5,LO$N@)Ls$N$?$a$K!$2sO)$r6&M-$7J1lPJi$J$$$3H,7P7P$"
$k!%%O!<%I%&%'%"5-=R8@8l$G$b!$2sO)$N6&M-$r;XDjG-MPJi$J$$!%

2sO)$N6&M-$O<!$N2 DKJ,N'G-$k!%

1. O@M}2sO)%l%Y%k$N6&M-!%
2. 5!G=%l%Y%k$N6&M-!%

A0<T$O!$Nc$($P$z_0 = f(x,y)$ Hz_1 = f(x,y)$ $NItJ,2sO)$r6&M-$7:G>.2=$9$k!$
$H$$$&h&JbNG$"$k!%3Nh&$J:Y$+$$:GE,2=$OO@M}9g@.7O$NC4EvG"$k!%
=>CF!$Evelyn GO6.2.3 @a$G=RY?5!G=%b%8%e!<%kXN%^%C%T%s%0$N%G%#%l
%/%F%#%VKh$j!$:GE,2=7d$9$$O@M}$r1 DN5!G=%b%8%e!<%k$K%^%C%T%s%0$9
$k!$$H$$$&=hM}N_$r9T$J$&!%

0lJ}!$8e<T$O1i;;4o!$%a%b%j$JINhjBg$-$J%l%Y%k$N6&M-$NOCG"$k!%$3
$N%l%Y%k$N6&M-GO!$;q8;$rGSB>E*$KMxMQ$7$J$$$H@5$7$/F0:n7J$$!%=>CF!$
F0:n%l%Y%k$GGSB>@)8f$N$?$a$N2sO)$r5-=R7J1lPJiJ$$!%D^$jEvelyn
GO!$$3Nh$&$J6&M-$r9T$J$&$?aK$O@)Ls%U%!%s%/%7%g%s$rMQ$$$FF0:n%l%Y
%k$+$i6&M-5;J/FOJi$J$$!%

3N$+$K!$>l9g$KhCFOGSB>@)8f$r9T$JoJ$/$F$b%3%s%U%j%/%H$,@8$8$J$$
3Hb"$k!%$7$+$7$=$Nh&$J>u67$r=hM}7O$,<+F0E*$KG'<1$9$kNO:FqG$"
$k!%=>$C$F!$5!G=%l%Y%k$N6&M-$r9TJ&>l9gKOI,$:@)Ls%U%!%s%/%7%g%s$rMQ
$$$F6&M-5l$k2sO)$r5-=R7J1lPJiJ$$!%

6.2.3 5!G=%b%8%e!<%kXN%^%C%T%s%0

Evelyn GO!$F0:n%b%8%e!<%kC10L$K%O!<%I%&%'%"$r5-=R$9$k!%F0:n%b%8%e!<
%k$O2sO)$N6&M-JIKh$k:GE,2=$r9MN8$KF~$l$F$$$J$$J,3dC10LG"$k!%5!G=
9g@.;~KO!$$3lr5!G=%b%8%e!<%k$K%^%C%T%s%0$9kI,MW,$"$k!%

5!G=%b%8%e!<%kXN%^%C%T%s%0J}K!$O<!$Nh&$K9T$J$&:$^$:J*M}E*@)Ls>eFC
$K%/%j%F%#%+%k$JItJ,KBP7FO!$%U%!%s%/%7%g%s$N%9%F!<%8r5iKJ,3d$7
$?<B9T%f%K%C%H$N5!G=%b%8%e!<%kXN%^%C%T%s%0J}K!$r@_7W<T$,5-=R9k!%%^%C
%T%s%0J}K!$r;XDj$7$J$$ItJ,KD$$$F$O!$%U%!%s%/%7%g%s$N1 DN%9%F!<%8$r

1 DN5 !G=%b%8%e! <%k$K5 !3#E*$K%^%C%T%s%0$9$k!%

<B9T%f%K%C%H$N5 !G=%b%8%e! <%k$X$N%^%C%T%s%0J}K!$O<!Nh$&$K9k: <B9T%f%K%C%H$O=PNCB&$Nsingal Kh$j0l0U$K;XDjG-$k!%l DN5 !G=%b%8%e! <%kK^Ha$F9g@.$7$?$$<B9T%f%K%C%H$N=PNCB&$Nsingal $N%j%9%H$r9g@.%G%#%l%/%F%#%VH7$EM?$(B$k!%

6.3 %U%!%s%/%7%g%s$N5!G=9g@.

<!$K!$C10l$N%U%!%s%/%7%g%s$N9g@.J}K!$r@bL@$9$k!%

%U%!%s%/%7%g%s$O!$4pK\E*KOA4$F%Q%$%W%i%$%s$K9g@.5l$k!%$7$+$7Nc$($P%2!<%H?t$,%/%j%F%#%+%k$G$"$k>l9g!$=hM}$9$k%G!<%?$N@-<A>e%Q%$%W%i%$%s=hM}$N8z2L$,4|BTG-J>l9gJI!$%Q%$%W%i%$%sF0:n$7J2sO)$r9g@.$7$?$$>l9g$,$"$k!%

$=$Nh&$J>l9g$K$O!$singal rAH_9go;k3HG%Q%$%W%i%$%sF0:n7J$$$h$&$KF0:n5-=R9k!%)>O$G!$=o$-9~$_HFI_=P7,F1;~KG$-$J$i%C%A$N5-=RNc$r<($7$?$,!$$=lHF1$8MWNN$G%Q%$%W%i%$%sF0:n7J$$$h$&$K5-=R9k!%

5F!$%Q%$%W%i%$%sF0:n$5$;$k$+$I$&$+K+$+$oi:!$%U%!%s%/%7%g%s$N5!G=9g@.$O!$(1) 0lO"$NF0:n$r%9%F!<%8$KJ,3d$7!$(2) %9%F!<%8Kh$K5!G=9g@.9k!$$H$$$&<j=g$G9T$J$&!%F0:n$r%9%F!<%8$KJ,3d$7F7$^$($P!$8e$Osignal $G5-=R$5l?ItJ,rAH_9go;2sO)H7$F9g@.$7!$singal $G5-=R$5l?ItJ,$r6.4@a$G=RYkh&$K9g@.$9lP$h$$!%

$=$3$GK\@a$G$O!$%U%!%s%/%7%g%s5!G=9g@.$NA0H>ItJ,!$%9%F!<%8J,3d$NJ}K!$K$D$$$F@bL@9k!%

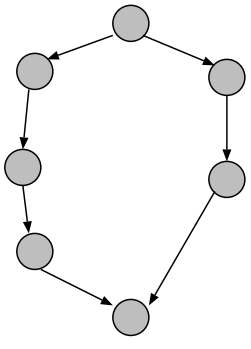
6.3.1 %9%F!<%8J,3d<jK!

%9%F!<%8J,3d$O!$3.4@a$G=R$Y$?$h$&$K9TJ&!%9JoA!$

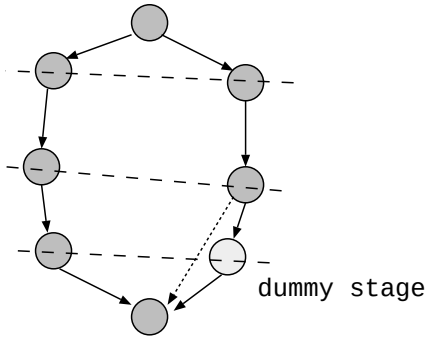
1. F0:n5-=R$+$i%G!<%?%U%m!<!&0%i%U$r:n@.$9$k!%
2. %G!<%?%U%m!<!&0%i%UKBP7$F!$%0%i%U$N>e$+$iF1$89b5K$"$ksingal $r7k$V“Ey9b@~” $r0z$/!%
3. “Ey9b@~” $N0LCV$G%9%F!<%8J,3d!%

$H$$$&<j=g$G%9%F!<%8J,3d$r9TJ&!%

C1=c$J>l9g$JiP3Nh&$K9$k3H$G%9%F!<%8J,3d$r9TJ&3H$,$G$-$kN@,!$>l9g$KhCFO4JC1KO“Ey9b@~” $rDj5A$G$-$J$$$3H,$"$k!%$=$Nh&$&$J>l9g$N%;%^%s%F%#%/%9$r@bL@9k!%



?^26: %9%F!<%8?t$N0[$J$k%Q%9$,9gN.9k



?^27: %@%_!<$NBeF~$rA^F~7F%9%F!<%8J,3d9k

%9%F!<%8?t$N0[$J$k%Q%9$,B8:_9k>l9g ?^26Nh$&$K!$9gN.CŒE@$^GK;j$k %Q%9$,$$$/D+$"$C$F!$$=3^GN%9%F!<%8?t$,%Q%9$KhC$F0[$Jkh$&$J>l 9g$,$"$k!%

3N>l9g!$<!$N2 DN9g@.J}K!N&$A!$$$$:l+$rA*Br$9$k!%

1. 5-=R$N0UL#$9$k2sO)$r$=$N$^$^9g@.9k!%
2. %9%F!<%8?t$,Ey$7$/$Jkh$&$KESCf$K%@%_!<$NBeF~$rA^F~$7$F9g@.$9$k!%

$^$:1$NU}K!$G$"$k$,!$$3$N>l9g9g@.$5l?2sO)$O%Q%$%W%i%$%sF0:n$7$J$$!% N.lk%G!<%?$,AB$G!$%Q%$%W%i%$%s=hM}$9$k%a%j%C%H$,$"$^jJ$$>l9gKO!$$3 $NU}K!$G9g@.9lPh$$!%

2 $N>l9g$G$"$k$,!$5!G=9g@.7O$O9gN.%]%$%s%H$ND>A0$K%@%_!<$NBeF~(%9%F!< %86-3&)$,$"$k$H2r<a$9$k!%$D$^$j!$?^26$Nh&$J%G!<%?%U%m!<!&0%i%U$KBP 7F$O?^27$Nh&$K2r<a$7"Ey9b@~"$rDj5A$9$k!%

%U%!%s%/%7%g%s8F$S=P$7 %U%!%s%/%7%g%s$r8F$S=P$9>l9g!$0lHLK=$N%U%!%s %/%7%g%s$,2?%5%$%/%k$G<B9T5lkN$+J,$+iJ$$!%3Nh&$J5-=R$r9g@.$9

```
singal data;
    ⋮
if ( cond == true ){
  data << 0;
}
```

?^28: cond NCMKhC$Fdata XNBeF~2s?t$,0[Jk

$k>l9g$K$O!$@_7W<T$O<!$N$$:l+$N9g@.J}K!$rA*Br9k!%

- 8F$S=P$5lk%U%!%s%/%7%g%s$rE83+$7$F%G!<%?%U%m!<!&0%i%U$r:n$k!%
  3N<BG"k,!$J,3d9g@.$,9TJ($J$$!$2sO)5,LO$,Bg$-$/JkNG5!G=9g
  @.K+$+$k%3%9%H$,A}Bg$9$k!$$JIN7gE@$,$"$k!%
- 8F$S=P$5lk%U%!%s%/%7%g%s$,2?%5%$%/%k$+$+k+9g@.%G%#%l%/%F%#%V$H
  7F;XDj9k!%
  J,3d9g@.$O9T$J$($k$,!$B>$N@_7WJQ99$KhC$F9g@.$rdjD>5J$/$FOJ
  iJ$$>l9g$,@8$:$k!%
- 8F$S=P$5lk%U%!%s%/%7%g%s$H%O%s%I%7%'%$/DL?.$r9T$J$&2sO)$r9g@.$9
  $k!%
  J,3d9g@.$,0BA4$K9TJ(k,!$@-G=/%2!<%H?t$NE@$GITMx$J2sO)$,9g@.$5
  lk!%

$=$l$>$l$K0lD90lC;$"kN$G!$5-=R9k2sO)$K9g$o$;$FE,@Z$KA*Br$9lP$h$$!%

if J8 if J8GO!$>r7o$rK~$?$9$+$I$&$+$Gsingal XNBeF~2s?t$,0[Jk>l9g$,
$"$k!%NcO($P?^28$Nh&JNcGO!$cond NCMKhC$Fdata XNBeF~2s?t$,0[
Jk!%3lr$=$N$^$^9%F!<%8J,3d9k$H!$cond NCMKhC$F%9%F!<%89=@.$,
JQoCF7$^$&!%

3N>l9g!$<!$N2<dN`$N5!G=9g@.$NJ}K!$,9M$(il$k:

- %@%_!<%9%F!<%8$rA^F~$7$F!$3F@a$N%9%F!<%8?t$rB7$($k!%
- 5-=R$N0UL#$9$k2sO)$r$=$N$^$^9g@.9k!%

%@%_!<%9%F!<%8$rA^F~$9$kJ}K!$G$O!:G$bCY$$$bNK9go;$FF0:n$9k?$a
@-G=$NE@$GITMxG"k,!$%O!<%I%&%'"$OC1=cKJ$k!%J$*!$%@%_!<%9%F!<%8$r

```
if ( cond == true ){
   data << 0;
}
else{
   data << data;
}
```

?^29: 0EL[$Nelse @a$,B8:_9kH9$k

A^F~9k2U=jG"k,!FCK;XDj7J1l$P5!G=9g@.7O$OE,Ev$KA^F~$9$k!%$7$+$7J*M}E*@)LsJI$NE@$G%/%j%F%#%+%k$J>19g$K$O@_7W<T$,;XDj9k3HbG$-$k!%

@h$N?^28$N>19gGO!$?^29 Nh$&$K%@%_!<$Nelse @a$K%@%_!<$NBeF~$,5-=R5l$F$$kbNH7$FC10l$N%Q%$%W%i%$%s$r9g@.$9$k!%

0lJ}!$5-=R$N0UL#9k2sO)r=N^$^9g@.$9$kJ}K!$G$O!$$=N^$^$G$O%Q%$%W%i%$%sF0:n$7$J$$2sO)$,9g@.$5lk!%3l$O!$D9$5$N0[Jk%Q%$%W%i%$%s$rJBNs$KF0:n5;kH!$J#?t%Q%$%W%i%$%s4V$G%G!<%?$NDI$$1[7,H/@8$9$k2DG=@-$,$"k+iG$"$k!%

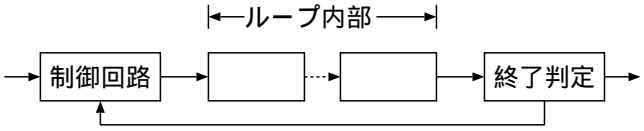
7+$7!$%G!<%?$r%Q%$%W%i%$%s$KEjF~7?=g=x$rJ]B8$9$k2sO)$rMQ0U9k3H$G!$if @a!$else @a$rJL!9$N%Q%$%W%i%$%s$H7F9g@.9k3H$,$G$-$k!%3NJ}K!GO!$@-G=$NE@GOM-MxG"k,!$%Q%$%W%i%$%s$N@)8fN?aN2sO)$,J#;($KJj!$2sO)5,LO$NA}Bg$r>7$/3HKJ$k!%

%k!<%W if J8$HF1MM!$%k!<%W(for %k!<%W!$while %k!<%W) KBP7FbC1=cKO“Ey9b@~” $rDj5A$G$-$J$$!%$3$3GO5!G=9g@.N?aN%k!<%W$N%;%^%s%F%#%/%9$r=RYk!%

5F!$%k!<%W$O<!Nh$&$KJ,N`G-$k!%

- %k!<%W2s?t$N>e8B$,@EE*$K7hDj$G$-$k$+H]$+!%
- AH$_9g$o$;2sO)E*$J%k!<%W(signal N_$G5-=R$5l?%k!<%W) $+!$=g=x2sO)E*%k!<%W(singal XNBeF~$r4^$`%k!<%W) $+!%

$^$:%k!<%W2s?t$N>e8B$,@EE*$K7hDj$G$-(Dj2s%k!<%W) $+$DAH$_9g$o$;2sO)E*$J%k!<%WG"k,!$$3lO%k!<%W$rA4$FE83+7?2sO)$r5!G=9g@.$9$k!%



?^30: %k!<%W$N5!G=9g@.

<!$K!$%k!<%W2s?t$N>e8B$,@EE*KO7hDjG-$:(ITDj2s%k!<%W) $+$DAH$_9g o;2sO)E*$J%k!<%W$O5!G=9g@.IT2DG=G"$k!%=>$CF3Nh$&$J5-=R$O5!G=9g @.;~%(%i!<$HJk[1)]!%

$=$7$F!$=g=x2sO)E*%k!<%WG"k,!$$3lOIj2s!$ITDj2s$K$+$+oi$:9g@. 2DG=$G$"$k!%

3Nh&$J%k!<%W$O?^30Nh$&$K9g@.9k!%9JoA%k!<%WFbIt$rDL>o$N%Q %$%W%i%$%sH7$F9g@.$7!$%k!<%W$NF~8}$K@)8f2sO)!$%k!<%W$N=P8}$K=*N;H=Dj N?aN2sO)$r9g@.$9$k!%%k!<%W$,%S%8!<$N>l9g$K$O!$@)8f2sO)$,B3$/%G!<%? $NEjF~$r%V%m%C%/9k!%

=g=x2sO)E*$JITDj2s%k!<%W$N$&$AL58B%k!<%WHJkb$N-FC$K!$>u67$KhC $FL58B%k!<%W$HJj$&$kbN$O!$%O!<%I%&%′%"H7$F=EBg$J%P%0HJCF7^ $&2DG=@-$,$"$k!%7+$7=hM}7O$,<+F0E*K3Nh$&$J%P%0$rH/8+$9k3HO6K aF:FqG"$k!%=>$C$F!$5!G=9g@.2DG=JbNr%O!<%I%&%′%"H7$F@5$7$/F0 :n$9kh$&$K9kNO!$@_7W<T$N@UG$$H9k!%ITDj2s%k!<%W$r;}$D2sO)$r@_7W 9k>l9gKOFC$K?5=E$KF0:n8!>Z$r9T$JoJ1lPJiJ$$!%

6.4 singal $N9g@.

$^$:!$F0:n5-=R$N4pK\$HJksingal $N5!G=9g@.J}K!$+$i@bL@$9$k!%

F0:n5-=RK*1k%W%j%_%F%#%VG"$ksingal $O!$%O!<%I%&%′%"H7FOHs>o $K9b5!G=$JbNG"$k!%9b5!G=$G$"$k$H$$$&3H$O!$MM!9$J<B8=J}K!$,9M$($i lk$H$$$&3HGb$"$k!%5!G=9g@.7O$O!$%O!<%I%&%′"NL$OA}$(FbB.$/F0:n 9kbN!CY/F$b9=oJ$$$+iGk@$1%7%s%W%k$JbNEy!$@_7W<T$NMM!9 $JMW5a$K=@Fp$K1~$(JJ1lPJiJ$$!%

[1)] 7>O$G=R$Ykh$&$KF0:n%7%_%e&l!<%?GO3Nh$&$J5-=R$O<uM}$5lk!%=>CF!$5!G=9g@. $rL\E*$H7J$$2sO)-Nc$($P%F%9%H%Y%s%A$r5-=R$9k?aK3Nh$&$J%k!<%W$rMQ$$$k$3 HO0l8~$K9=oJ$$!%

6.4.1 J}?K

7k6INH3m!$singal HOF14 |5!9=$r; }$D5-212sO)G"$k!%=>CF!$singal $N 9g@.J}K!$r7hakMWAGH7$F!$

- ;HMQ9k5-212sO) : %U%j%C%W%U%m%C%W$r;H$&$+!$%i%C%A$r;H$&$+!%
- F14 |$N6/$5: FI$_=P$7$H=q$-9~$_$,F1;~KG$-$k$+!%

$N2 D,9M$(B$ilk!%

3N$&$A!$F14 |$N6/5K4X7F$O!$5>OGb=RY?h&$K!$F0:n5-=RH7$F5-=R$9$k!%

=>CF!$;HMQ$9$k5-212sO)$N<dN`N_9g@.%G%#%l%/%F%#%VH7$FM?$($k!%

6.4.2 %/%m%C%/$N5,Dj

H3mG!$Evelyn $NF0:n$K$O%/%m%C%/$OM[$K5-=R$5lJ$$!"F14 |2sO)-D^$jsingal $,%/%m%C%/$KF14 |7FF0:n9k2sO)$r9g@.$9$k>19g$K$O!$%/%m%C%/$rDj5A$9kI,MW,$"$k!%

Evelyn GO%/%m%C%/$NDj5A$O9g@.%G%#%l%/%F%#%VKhCFM?$($k!%9g@.%G%#%l%/%F%#%VGO<!Nh$&$J%/%m%C%/$rDj5A$G$-$k!%

- G$0U8D$Nexternal clock(30It$+$i6!5k5l$k%/%m%C%/)
- G$0U8D$Ngated clock

7+$7!$O@M}9g@./:GE,2=7ONCfK$OC10l$N%/%m%C%/K7$+BP1~$7$F$$$J$$$bNb$"$k!%2<N.9)Dx$N@)Ls$rK~$?$9h&$J9g@.%G%#%l%/%F%#%V$rM?$($J$/$FOJiJ$$!%

%/%m%C%/$rDj5A$7$?8e$G!$3Fsingal KBP7FI$N%/%m%C%/$HF14 |9k$+$r;X<(9k9g@.%G%#%l%/%F%#%V$rM?$(k3HG!$F14 |2sO)$r5!G=9g@.9k3H$,$G$-$k!%

$^$?Evelyn $OHsF14 |2sO)$r9g@.9k3HbG$-$k!%HsF14 |2sO)$r9g@.$9kK$Osingal $rHsF14 |<0%i%C%A$H7F5!G=9g@.9lPh$$!%

6.4.3 5-21AG;R$N;XDj

$^$:5-21AG;R$NA*Br$K$D$$F!%5-21AG;R$OOJ2<$N3 <dN`$+$iA*Br9k!%

- %U%j%C%W%U%m%C%W(%(%C%8!&H%j%,7?)
- %H%i%s%9%Z%"%l%s%H!&i%C%A(%Q%k%9!&H%j%,7?)
- HsF14 |<0%i%C%A

%(%C%8!&H%j%,7?$rA*Br$7$?>19g$K$O!$%/%m%C%/?.9fL>$bF1;~$K;XDj9k!%%Q%k%9!&H%j%,7?$rA*Br$7$?>19g$K$O!$@)8f?.9f$rL@<(E*$K;XDj7J$/$b<+F0

E*$K9g@.$9$k!%

$^$?!$%/%m%C%/$rA4$/Dj5A$;$:!$A4FNsingal $KHsF14|<0%i%C%A$rA*Br9l $P!$HsF14|2sO)$r5!G=9g@.$9k3H,G-$k!%

J*!$AG;R$X$N%j%;%C%H$NI,MW@-$O!$5!G=9g@.7O$,<+F0H=Dj$9$k!%$9Jo$A!$@k8@;~KCM,=i4|2=5l$F$$$ksingal KD$$$F$O%j%;%C%HIU$-$N5-21AG;R$rMQ $$$F9g@.9k!%L@<(E*$K=i4|2=$5lF$$J$>19g$K$O%j%;%C%H$J7$NAG;R$rMQ $$$k!%

7 F0:n%7%_%e&l!<%7%g&s

K\@aGO!$Evelyn $NF0:n%7%_%e&l!<%?$K$D$$$F@bL@9k!%$^$:F0:n%7%_%e&l!<%?$,%5%]!<%H$9$k5!G=$K$D$$F=R$Y!$F0:n%7%_%e&l!<%7%g&s<jK!KD$$F=RYk!%

7.1 F0:n%7%_%e&l!<%?$,Ds6!$9$k5!9=

F0:n%l%Y%kHDL $rMQ$$$?@_7W$NMxE@$N1 DO!$F0:n@_7W$NCJ3,$G%7%_%e&l!<%7%g&s$KhkF0:n8!>Z$r9T$J$($k$H$$$&E@G"$k!%3+H/$NAa$$CJ3,$G%"%k%4%j%:%`%l%Y%k$N%P%0$r<h$j=|$/$3H,G-k?$a!$3+H/8zN($,8~>e$9$k!%

Evelyn $NF0:n%7%_%e&l!<%?$b!$F0:n%7%_%e&l!<%7%g&s/8!>Z$r6/NO$K%5%]!<%H9k$?$a$K<o!9$N5!9=$r@9$j9~$`!%

7.1.1 %F%9%H%Y%s%A$N5-=R

F0:n%7%_%e&l!<%7%g&s;~$K!$@_7WBP>]$@$1GJ$/!$@_7WBP>]N^oj$K%F%9%H%Y%s%A$r@\B3$7$F7O$r9=C[$7!$7OA4BN$r%7%_%e&l!<%7%g&s9k$H$$&3H$,$h$/$"$k!%

@_7WBP>]C1BNGOCj>]E*$JF0:n$NOUL#$,J,$+jE$i$$!$"$k$$O@_7WBP>]$N30It%$%s%?%U%'!<%9$,J#;($G$"$k!$$H$$&h&$J>19g$K$O!$%F%9%H%Y%s%A$r4^$`7OA4BN$,@5$7$/F0:n$9k+3NG'9k$H@_7W8!>Z$,9T$J$$0W$$+iG$"$k!%

3Nh&$JL\E*$N$?$a$K5-=R$5lk%F%9%H%Y%s%A$O!$Ev$?$jA0N3H@$,5!G=9g@.$5lkbNGO$J$$!%$=$3$G!$$=Nh$&$J5-=Rr9$k>19g$K$O!$6>O$G=R$Y$?$h$&$J5!G=9g@.N?aN5,Dj$rK~$?5J$/$F$b9=$o$J$$$h$&$K9k!%Nc$($PAH$_9g$o$;2sO)E*$JL58B%k!<%W$r%F%9%H%Y%s%A$KMQ$$$k3H$,$G$-$kh&K9$k!%

7+$7!$5!G=9g@.9kDbjG5!G=9g@.IT2DG=JbNr5-=R7F7^$&$N$bLdBj$G$"$k!%$=$3$G!$Evelyn GO5!G=9g@.2DG=JbNHIT2DG=JbNr8@8l;E

MMH7$FL@3N$K5,Dj9k!%$=$7$F!$%3%s%Q%$%k;~$K%*%W%7%g%srIU1k3HG9g@.%b!<%I$HHs9g@.%b!<%I$r@Z$j49$(kh$&$K9k!%

7.1.2 ;~AjO@M}<05-=R$N%5%]!<%H

9g@.rI,MWH7J$$Cj>]E*$J5-=R$N%5%]!<%Hr5iK?JaF!$;~AjO@M}<05-=R$b%5%]!<%H9k!%

6aG/$N2sO)$NBg5,LO2=$K7A<0E*@_7W8!>Z5;=Q$,$D$$$F3J$$$H$$$&3Hb"$j!$F0:n%7%_%e&l!<%7%g%sKhCF=iaFK\3JE*$J@_7W8!>Z$,9TJ(kH$$$&3H$b>/$J$/$J$$$[5]!%

$^$?!Nc($P6&M-%a%b%j7?JBNs7W;;5!$K$*$$$F%=%U%H%&%'%"$H%O!<%I%&%'%"$N%$%s%?%U%'!<%9$r5,Dj9k%a%b%j%b%G%kJI!$%$%s%?%U%'!<%9$NCj>]EY$N9b$$;EMM$r;~AjO@M}<0$KhC$F4J7i$K5,Dj7F$$$kbN$bB?$$!%

$=$3$G!$F0:n%7%_%e&l!<%?$G;~AjO@M}<05-=R$r%5%]!<%H9k!%3lKhCF Evelyn Kh$kF0:n5-=R$,hj9b$$Cj>]%l%Y%k$N;EMM$rK~$?$7$F$$k$+8!>Z$G$-$kh&KJ$k!%;~AjO@M}<0$Khk;EMM5-=R$,%F%9%H%Y%s%A$hjb4J7i$K5-=R$G$-$k>l9gKO!$@_7W8!>Z$N%3%9%H$,BgI}$K:o8:G-k3H,4|BT5l$k!%

0J>e5!9=$rF0:n%7%_%e&l!<%?$,%5%]!<%H9k5!9=KD$$F=RY?!%3liN%5%]!<%HKh$jF0:n%l%Y%k@_7W8!/%G%P%C%0$CHs>o$K8zN(E*JbNHJk3H$,M=A[$5lk!%

5F!$0J2<$G$OF0:n%7%_%e&l!<%?$N9=@.J}K!$r=R$Y$k!%

7.2 Evelyn $NF0:n%b%G%k

F0:n%7%_%e&l!<%?$N9=@.J}K!$K$D$$F@bL@9kA0$K!$Evelyn $NF0:n%b%G%k$K$D$$F=RYk!%F0:n%b%G%kKD$$F$O4>O$G7Z$/=R$Y$?$,!$$3$3$G$O%7%_%e&l!<%7%g%s$NN)>l$+$i$NEvelyn $NF0:n%b%G%k$K$D$$F@bL@9k!%

Evelyn $O%m!<%l%Y%k$G$O<B9T%f%K%C%H$,F0:n$NC10L$HJk!%<B9T%f%K%C%H$O!$A4FNF~NOsingal $GM-8z$JCM$,B7$$!$$+$D=PNOsingal $,%V%m%C%/$5lF$$J$$$H$-$K!$F~NOsingal $+$iCMrFI_=P$7!$1i;;$r<B9T$7!$7k2L$r=PNOsingal $K=q$-9~$`!%

%O%$%l%Y%k$G$O!$%b%8%e!<%k$,8_$$$KAj<j$N%U%!%s%/%7%g%s$r8F$S=P$7"$&$3HGF0:n9k!%7+$7Evelyn $N%U%!%s%/%7%g%s$O@EE*$K@8@.$5lk1 DN%$%s%9%?%s%"$=>CF!$Evelyn $N%W%m%0%i`$O!$%U%!%s%/%7%g%s$rA4$FE83+$7$?!$l DN<B9T%f%K%C%H$N%M%C%H%o!<%/$HB*$($F$h$$!%

F0:n%7%_%e&l!<%7%g&sHO!$@EE*$K9=C[7?<B9T%f%K%C%H$N%M%C%H%o!<%/$K%G!<%?$rN.$7$FF0:n$5$;$k3H$KB>$JiJ$$!%

7.3 %7%_%e&l!<%7%g&s<jK!

$=$lGO!$A0@a$G=RY?F0:n%b%G%k$r8zN(B*$K%7%_%e&l!<%7%g&s9k$?$a$NJ}K!$K$D$$F=RYk!%

%7%_%e&l!<%7%g&s9k>l9g!$<B9T%f%K%C%H$N<B9T=g=x$N%9%1%8%e!<%j%s%0$,LdBjKJ$k!%$=3GK\@aGO!$<B9T%f%K%C%H$N%9%1%8%e!<%j%s%0J}K!KD$$F=RYk!%$^$:!$7.3.1@a$G%9%1%8%e!<%j%s%0>eLdBjKJ$kE@$K$D$$F=R$Y!$7.3.2@a$G%9%1%8%e!<%j%s%0<jK!$K$D$$F=RYk!%

7.3.1 @)Ls%U%!%s%/%7%g&s$N<B9T=g=x

@)Ls%U%!%s%/%7%g&s$O!$J#?t$N8F$S=P7rF1;~$K=hM}$9$k%U%!%s%/%7%g&s$G$"$k!%=>CF!$@)Ls%U%!%s%/%7%g&s$r<B9T9kA0$KEv3:%5%$%/%kG=$N@)Ls%U%!%s%/%7%g&s$r8F$S=P$9%U%!%s%/%7%g&s$rA4$FGD0.7F$$J1lPJiJ$$!%

7+$7$3$3$GLdBj$,@8$8$k!%$"kAH_9go;2sO)E*$J@)Ls%U%!%s%/%7%g&s$N<B9T7k2LKhCFJL$N@)Ls%U%!%s%/%7%g&s$r<B9T9k$+7h$^$k>l9g$,$"$kNG$"$k!%3N>l9g@h$KA0<T$r<B9T7F$+$i8e<T$r<B9T$7$J$$$H@5$7$$F0:nHJiJ$$!%

=>CF!$C1$K8F$S=P$5lk2DG=@-N"$k@)Ls%U%!%s%/%7%g&s$rGD0.9k$@$1GJ$/!$$=$N<B9T=g=x%9%1%8%e!<%j%s%0KbCm0U9kI,MW$,$"$k!%

@)Ls%U%!%s%/%7%g&s$N<B9T=g=x$O<!Nh$&$K7hDj9lPh$$:

1. M=$aA4$F$N%9%F!<%8$KBP7F!$$=$N%9%F!<%8$,<B9T9k2DG=@-N"$k@)Ls%U%!%s%/%7%g&s4V$N0MB84X78%0%i%U$r:n@.$7F*$/
2. Ev3:%5%$%/%k$G<B9T9k2DG=@-N"$k@)Ls%U%!%s%/%7%g&s$KBP7F!$$=$N0MB84X78%0%i%U$KL7=b7J$$h$&$K!$@)Ls%U%!%s%/%7%g&s$N<B9T=g=x$r7hDj$9$k!%

b7@)Ls%U%!%s%/%7%g&s0MB8%0%i%U$KL7=b$,B8:_9k$?$a$K@)Ls%U%!%s%/%7%g%s$N<B9T=g=x$,7hDj$G$-$J$$$H7?$i!$$=lOAH$_9g$o$;2sO)$N%k!<%W$,B8:_$7$F$$k$H$$&3HKJ$k!%=>$CF=Nh$&$J>l9g$O<B9T;~%(%i!<$HJk!%

=>CF!$@)Ls%U%!%s%/%7%g&s$r<B9T9k2DG=@-N"$k%W%m%;%9$N<B9T=g=x$O<!$Nh&$K7hDj$9lP$h$$:$^$:@)Ls%U%!%s%/%7%g&s$r8F$S=P$92DG=@-$NJ%U%!%s%/%7%g&s$rA4$F<B9T9k!%$=$7$F@)Ls%U%!%s%/%7%g&s$O@)Ls%U%!%s%/%7%g

%s0MB8%0%i%U$N>e$+$i<B9T$7$F$$/!%

7.3.2 <B9T%9%1%8%e!<%j%s%0

0J>e=RY?3H$r<B8=$9$k<B9T%9%1%8%e!<%j%s%0<jK!$r=R$Y$k!%

%"%k%4%j%:%`KO2DNsingal $N%j%9%H$rMQ$$$k1DO$^$@<B9T5l$F$$J$$singal $N%j%9%H(L$<B9Tsingal %j%9%H) G"$j!$$b$&1$D$O<B9T$O40N;7?$,=PNOB&singal N?$a%V%m%C%/$5lF$$kbN$N%j%9%H(%V%m%C%/%Isingal %j%9%H) G"$k!%

<B9T%"%k%4%j%:%`$r0J2<$K<($9!%

1. Ev3:%5%$%/%k$G?7$?$K@8@.5l$?<B9T%f%K%C%H$rL$<B9Tsingal %j%9%H$K2C$($k!%
2. L$<B9Tsingal %j%9%H$NCf$+$iF~NOB&singal $,%V%m%C%/$5lF$$J$<B9T%f%K%C%H$r<h$j=P$7!$%o!<%-%s%0%a%b%j$K0\F0$9$k!%
3. %o!<%-%s%0%a%b%jK"$k<B9T%f%K%C%H$N$&$A!$@)Ls%U%!%s%/%7%g%s$r8F$S=P$92DG=@-N"kbNrA0@a$G=R$Y$?<B9T=g=x$K=>CF<B9T9k!%<B9T7k2L$O=PNOB&singal KO=q$-9~$^$:JL$N>l=j$KJ];}$7F*$/!%<B9T%f%K%C%H$O%V%m%C%/%Isingal %j%9%H$K0\$9!%
4. $=$l0J30$N<B9T2DG=$JbN$r<B9T$9$k!%2 $HF1MM$K<B9T7k2LOJLN>l=j$KJ]B8$7!$<B9T%f%K%C%H$O%V%m%C%/%Isingal %j%9%H$K2C$($k!%
5. %V%m%C%/%Isingal %j%9%HCf$N<B9T%f%K%C%H$N$&$A!$=PNOB&singal $,%V%m%C%/$5lF$$J$$b$N!$%k!<%W$,%V%m%C%/$5lF$$J$$bNK$D$$F<B9T7k2L$r=PNOB&singal $K=q$-9~$`!%F1;~$KF~NOB&singal $N%V%m%C%/$r2r=|9k!%<B9T%f%K%C%H$O=*N;$5$;$k!%
6. 6 KhCF=PNOB&singal $N%V%m%C%/$,2r=|5l$?$bNK$D$$F<B9T7k2L$r=PNOB&singal $K=q$-9~$`!%F1;~$KF~NOB&singal $N%V%m%C%/$r2r=|9k!%<B9T%f%K%C%H$O=*N;$5$;$k!%
7. <}B+9k$^$G5$r7+$jJV$9!%

8 $*$ojK

K\9FGOF0:n%l%Y%kHDL Evelyn $rDs0F$7$?!%

Evelyn $OF0:n5-=R$K!$CJ3,E*$K>\:Y$J@_7W>pJs$rIU2C7F$$/$H$$&%"%W%m!<%A$r:N$C$F$$k!%=N?a!$O@M}9g@.7O$JI+iN%U%#!<%I%P%C%/$,$"C?>l9gKb!$=$N%U%#!<%I%P%C%/%k!<%W$r:G>.8B$KM^$($k3H$,$G$-!$@_7WJQ

9 9$N%3%9%H$,BgI}$K:o8:$9k3H,G-$k!%

Evelyn GO!$%O!<%I%&%'%"$rF0:nC10L$K5-=R$9$k!%F0:n$r;~4VJ}8~$K5-=R$9k?$a!$0lO"$NF0:n$r<+A3$J7A$G5-=R9k3H$,$G$-$k!%

3Nh&J3H,2DG=HJC?%]%$%s%H$N1 DH7F!$singal $,5s$2il$k!%F14|5!9=$H5-212sO)$r%;%C%H$K7?singal KhCF!$9g@.2DG=@-$r5>@7K;$:$K!$F0:nC10L;~4VJ}8~$N%O!<%I%&%'%"5-=R$r2DG=$K7?!%

%9%F!<%86-3&$rJQ?t$Khj;XDj9k3N%"%W%m!<%A$O!$H>=g=xE*$+$D=@Fp$J;~4V4X78$r5-=RG-!$$^$?@_7WJQ99$rMF0W$K9T$J$($k!%3Nh&$J;~4V4X785-=R$O!$6aG/CmL\$5lF$$kHsF14|2sO)HN?FOB@-$b9b$$H9M$($ilk!%

K\9FGO5!G=9g@.<jK!KD$$F$b=R$Y$?!%Evelyn $O!$F0:n5-=R$NCj>]EY$,9b$$$?$a9g@.2DG=@-$r5?Ld;k5l$,$AG"$k!%$7$+$7!$%U%!%s%/%7%g%s$r%9%F!<%8$KJ,3d$5$($7F7$^$($P!$$"HO3F%9%F!<%8rAH_9go;2sO)$H%i%C%A$G<B8=9k$@$1JN$G!$$8+$?L\Dx5!G=9g@.$O:FqGOJ$$!%

2C$($F!$9g@.%G%#%l%/%F%#%V$Khj:Y$+$J5!G=9g@.J}K!$r;XDj$9k3H,G-$kE@$bBg$-$J%]%$%s%H$G$"$k!%

B>$NF0:n%l%Y%k$G$O!$5-=R$NCj>]EY$H9g@.G=NO$rN>N)$5$;$k$?$a$K!$5-=R$NBP>]$r8BDj9k$H$$&%"%W%m!<%A$r:N$C$F$$kbN$,B?$$!%

$=$lKBP7Evelyn GO!%9g@.%G%#%l%/%F%#%VKh$j9g@.J}K!$r:Y$+$/;X<(9k3H$G5-=R$NCj>]EY$H9g@.G=NO$N%H%l!<%I%*%U$r9b$$%l%Y%k$G%P%i%s%9$5$;$F$$k!%=N?$aEvelyn $rFCDj$NJ,Ln$K8B$i$:!$$lHL$N%O!<%I%&%'%"$N@_7W$K3hMQ$G$-$k!%

5F!$K\9F$G$O5!G=%l%Y%kHDL KD$$F87$7$/HcH=7F$-$?!%7$+$7Evelyn Nh$&$J%O!<%I%&%'%"5-=R$,2DG=$JNO!$<B$NH3$m5!G=%l%Y%kHDL H=$N=hM}7O$NO@M}9g@.5;=QKhkH3m$,Bg$-$$!%9Jo$A!$Evelyn $r@_7W$9kK$"$?CF!$5!G=%l%Y%k$N@_7W5-=RK^$GJQ49$G$-$l$PK~B-$G$-$k%/%*%j%F%#$N2sO)$,O@M}9g@.G-kH$$&3H$rA0Ds$H7F$$kNG$"$k!%

:#$^$G$O!$5!G=%l%Y%k$N5-=R$rK~B-G-$k%/%*%j%F%#$GO@M}9g@.9k3H$,L\I8$G$"$C$?!%$=$7$7$F:#!$$=$NO@M}9g@.5;=Q$O@.=O$7!$$=$N8B3&$,8+$($DD"$k!%Evelyn $O@_7W<+F02=$NJ,Ln$N<!$N0lJbG"$k!%

<UK-

K\8&5f$N5!2q$rM?$($F2<5j!$E,@Z$J8f;XF3$r;r$oC?IYEDbC<#65<x$K?<?S$J<U0U$rI=$7$^$9!#

$^$?!$5.=E$J8f=u8@$r$$?$@$$$??9bC0lO:=u65<x!$8^Eg@5M5=u<j$K?<$/46<UCW$7$^$9!%

5i$K!$F|:"CH$+$/8fJ\Z%2<5C$?5~ETBg3XBg3X1!9)3X8&5f2J>pJs9)3X@l96IYED8&5f<<$N=t7;$K46<UCW7^$9!%

:G8e$K!$%a%s%?!<!&0%i%U%#C%/%9!&8%c%Q%s3t<02q<R$NHigher Education Program $N0l4D$H7F@=IJ$H%5!<%S%9$r$4Ds6!D:$$$?3H$K46<U$7$^$9!%

;29MJ88%

[1] 0B1:42?M,;3ED51I',B>:FC=8!¥O!<%I%&%'%"5-=R8@8l-?7$7$$%7%9%F%¨@_7W4D6-$N<B8=$K8~1F-!W,>pJs=hM}, Vol. 33, No. 11 (1992).

[2] @>ED9@0l,;3ED985W,?@8M>0;V, Kay, A., LnB<=SIW:%O!<%I%&%'%"%3%s%Q%$%iBach, ?.3X5;JsCPSY97–87, pp. 143–148 (1997).

[3] <cNS0lIR,8ENS5*:H,B>:EAAwMQLSI $rF0:n9g@.$G3+H/!$5!G=@_7W$N4|4V$,1/10 $KC;=L,F|7P%(%l%/%H%m%K%/%92–12, No. 655, pp. 147–169 (1996).

[4] ?9K\5.G7,@FF#0l;V,CfB<9(,KQBYM4,Cf_74n;OO::J}<0%l%Y%k5-=R8@8lAIDL $rMQ$$?9b@-G=%W%m%;%C%5@_7W;Y1g,>p=h8&Js96–ARC–121–8, 96–DA–82–8, pp. 57–64 (1996).

[5] =.K\0l5W,J!EgD>?M,8^Eg@5M5,?9bC0lO:,CfEg9@,IYEDbC<#:D6JBNs7W;;5!JUMP-1 $N%-%&C%7%&%7%9%F%¨$NO@M}@_7W8!>Z,>pJs=hM}8&5f2qJs9p96–ARC–119–38, pp. 221–226 (1996).