

DA RESTITUIRE INSIEME AGLI ELABORATI e A TUTTI I FOGLI
 → NON USARE FOGLI NON TIMBRATI
 → ANDARE IN BAGNO PRIMA DELL'INIZIO DELLA PROVA
 → NO FOGLI PERSONALI, NO TELEFONI, SMARTPHONE, ETC

COGNOME _____

NOME _____

SVOLGIMENTO DELLA PROVA:

□ PER GLI STUDENTI DI "ARCHITETTURA DEI CALCOLATORI – A.A. 2015/16, 16/17, 17/18, 18/19": es. N.1+2+3+7.

NOTA: per l'esercizio 7 dovranno essere consegnati DUE files: il file del programma VERILOG e il file relativo all'output (screenshot o copy/paste)

1) [11/30] Trovare il codice assembly MIPS corrispondente al seguente programma (usando solo e unicamente istruzioni della tabella sottostante e rispettando le convenzioni di utilizzazione dei registri dell'assembly MIPS riportate qua sotto per riferimento).

```
int a[10] = {51, 11, 32, 34, 11, 51, 46, 5, 62, 27};
```

```
void shellsort(int a[], int n)
{
    int i, j, increment, tmp;
    for(increment = n/2; increment > 0; increment /= 2) {
        for(i = increment; i < n; i++) {
            tmp = a[i];
            for(j = i; j >= increment; j -= increment) {
                if(tmp < a[j-increment])
                    a[j] = a[j-increment];
                else
                    break;
            }
            a[j] = tmp;
        }
    }
}
```

```
int main()
{
    int i, n = 10;
    shellsort(a,n);
    for(i = 0; i < n; i++) {
        print_int(a[i]);
        print_string(" ");
    }
    exit(0);
}
```

Instructions

Opcode+Func (hexadecimal)	Instruction	Example	Meaning	Comments
00+20/00+21	add	add/addu \$1,\$2,\$3	\$1 = \$2 + \$3	(signed/unsigned) 3 operands; exception possible
00+22/00+23	subtract	sub/subu \$1,\$2,\$3	\$1 = \$2 - \$3	(signed/unsigned) 3 operands; exception possible
08/09	add immediate	addi/addiu \$1,\$2,100	\$1 = \$2 + 100	(signed/unsigned) + constant ; exception possible
00+18/00+19	multiplication	mult/multu \$1, \$2	Hi,Lo=\$1 x \$2	(signed/unsigned) 64-bit Product ; result in Hi,Lo
00+1A/00+1B	division	div/divu \$1, \$2	Hi=\$1 % \$2, Lo = \$1 / \$2	(signed/unsigned) division
00+10/00+12	move from Hi / move from Lo	mfhi/mflo \$1	\$1 = Hi (\$1 = Lo)	Create copy of Hi (Create a copy of Lo)
00+2A/00+2B	set on less than	slt/sltu \$1,\$2,\$3	if (\$2 < \$3) \$1 = 1; else \$1 = 0	(signed/unsigned) compare \$2 and \$3 (less than)
0A/0B	set on less than immediate	slti/sltiu \$1,\$2,100	if (\$2 < 100) \$1 = 1; else \$1 = 0	(signed/unsigned) compare \$2 and constant (less than)
00+24/25/26/27	and / or / xor / nor	and/or/xor/nor \$1,\$2,\$3	\$1=\$2&\$3 / \$2 \$3 / \$2^\$3 / ~(S2 \$3)	3 register operands; Logical AND/OR/XOR/NOR
0C/0D/0E	and / or / xor immediate	andi/ori/xori \$1,\$2,100	\$1 = \$2 & 100 / \$2 100 / \$2 ^ 100	Logical AND/OR/XOR register, constant
00+00	shift left logical	sll \$1,\$2,10	\$1 = \$2 << 10	Shift left by constant
00+02/00+03	shift right (l=logical,a=arithmetic)	srl/sra \$1,\$2,10	\$1 = \$2 >> 10	Shift right by constant (for arithmetic: sign is preserved)
00+04	shift left logical	sllv \$1,\$2,10	\$1 = \$2 << \$3	Shift left by variable
00+06/00+07	shift right (l=logical,a=arithmetic)	srlv/srav \$1,\$2,10	\$1 = \$2 >> \$3	Shift right by variable (for arithmetic: sign is preserved)
23/20	load word / load byte	lw/lb \$1,100(\$2)	\$1 = Memory[\$2+100]	Data from memory to register
24	load byte unsigned	lbu \$1,100(\$2)	\$1 = Memory[\$2+100]	Data from mem. To reg.; no sign extension
2B/28	store word / store byte	sw/sb \$1,100(\$2)	Memory[\$2+100] = \$1	Data from register to memory
0F	load upper immediate	lui \$1,0x1234	\$1=0x1234'0000	load most significant 16 bits
PSEUDOINSTRUCTION	load address	la \$1,var	\$1 = &var	Load address of var (lui \$1,H16(&var);ori \$1, L16(&var)) H16/L16=high/low 16 bits of &var
02	jump	j 10000	go to 10000	Jump to target address
00+08	jump register	jr \$31	go to \$31	For switch, procedure return
03	jump and link	jal 10000	\$31 = PC + 4; go to 10000	For procedure call
04	branch on equal	beq \$1,\$2,100	if (\$1 == \$2) go to PC+4+100	Equal test; PC relative branch
05	branch on not equal	bne \$1,\$2,100	if (\$1 != \$2) go to PC+4+100	Not equal test; PC relative
00+0C	syscall	syscall	call OS service \$v0	See table of system calls below
10+10,rs=10	rfe	rfe	shift right (k,e) bits in STATUS reg	Exit Kernel Mode, Enable Interrupts
PSEUDOINSTRUCTION	branch unconditional	b 100	go to PC+4+100	PC relative branch (e.g., beq \$0,\$0,100)
PSEUDOINSTRUCTION	no operation	nop	do nothing	Do nothing (e.g. sll \$0,\$0,0)
30	load-linked	ll \$1,100(\$2)	\$1=Memory[\$2+100]	Read and start to monitor the given memory location
38	store-conditional	sc \$1,100(\$2)	Memory[\$2+100]=\$1 or →	return 0 if a coherence action happens since the previous ll (\$1 must be different from 0)
11+00 fmt=10/11	add.s / add.d	add.s \$f0,\$f2,\$f4	\$f0=\$f2+\$f4	Single and double precision add
11+01 fmt=10/11	sub.s / sub.d	sub.s \$f0,\$f2,\$f4	\$f0=\$f2-\$f4	Single and double precision subtraction
11+02 fmt=10/11	mul.s / mul.d	mul.s \$f0,\$f2,\$f4	\$f0=\$f2*\$f4	Single and double precision multiplication
11+03 fmt=10/11	div.s / div.d	div.s \$f0,\$f2,\$f4	\$f0=\$f2/\$f4	Single and double precision division
11+05 fmt=10/11	abs.s / abs.d	abs.s \$f0,\$f2	\$f0=ABS(\$f2)	Single and double precision absolute value
11+06 fmt=10/11	mov.s / mov.d	mov.s \$f0,\$f2	\$f0←\$f2	Single and double precision move
11+07 fmt=10/11	neg.s / neg.d	neg.s \$f0,\$f2	\$f0= - (\$f2)	Single and double precision opposite value
11+3C (31,32,3D,3E,3F) fmt=10/11	c.lt.s / c.lt.d (ne,eq,gt,le,ge)	c.lt.s \$f0,\$f2	Temp=(\$f0<\$f2)	Single and double; compare \$f0 and \$f2 < , = , > , <= , >=
11+00 fmt=4/0	move to/from coprocessor 1	mtc1/mfc1 \$1,\$f2	\$f2=\$1 / \$1=\$f2	Move \$1 to/from C1 reg. \$f2 (no conversion)
10+00 fmt=4/0	move to/from coprocessor 0	mtc0/mfc0 \$1,\$f2	\$c2=\$1 / \$1=\$c2	Move \$1 to/from C0 reg. \$f2 (no conversion)
11+00 fmt=6/2	move to/from control reg of cop.1	ctc1/cfc1 \$1,\$c2	\$c2=\$1 / \$1=\$c2	Move \$1 to/from C1-CONTROL register
11 fmt=8, ft=1/0	branch on true/false	bclt/bclf label	If (Temp == true/false) go to label	Temp is 'Condition-Code'
31/39	load/store floating point (32bit)	lwc1/swc1 \$f0,0(\$1)	\$f0←Memory[\$1] / Memory[\$1]←\$f0	Data from FP (C1) register to memory
11+21, fmt=10/11+22, fmt=11	convert from/to single to/from double	cvt.d.s/cvt.s.d \$f0,\$f2	\$f0=(double)\$f2/\$f0=(single)\$f2	Type conversion
11+24, fmt=11/11+20	convert from/to single to/from integer	cvt.w.s/cvt.s.w \$f1,\$f0	\$f1=(int)\$f0 / \$f0=(single)\$f2	Type conversion

Register Usage

Name	Reg. Num.	Usage
\$zero	0	The constant value 0
\$s0-\$s7	16-23	Saved
\$t0-\$t9	8-15,24-25	Temporaries
\$a0-\$a3	4-7	Arguments

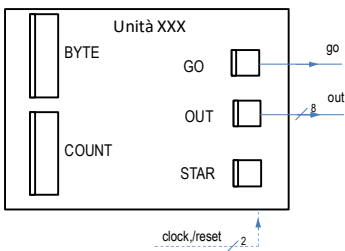
Name	Reg.Num.	Usage
\$v0-\$v1	2-3	Results
\$fp, \$sp	30,29	frame pointer, stack pointer
\$ra, \$gp	31,28	return address, global pointer
\$k0-\$k1	26,27	Kernel usage

Reg. Num.	Usage
\$f0, \$f2	Return values
\$f12,\$f14	Function arguments
\$f20,\$f22,\$f24,\$f26,\$f28,\$f30	Saved registers
\$f4,\$f6,\$f8,\$f10,\$f16,\$f18	Temporaries registers

System calls

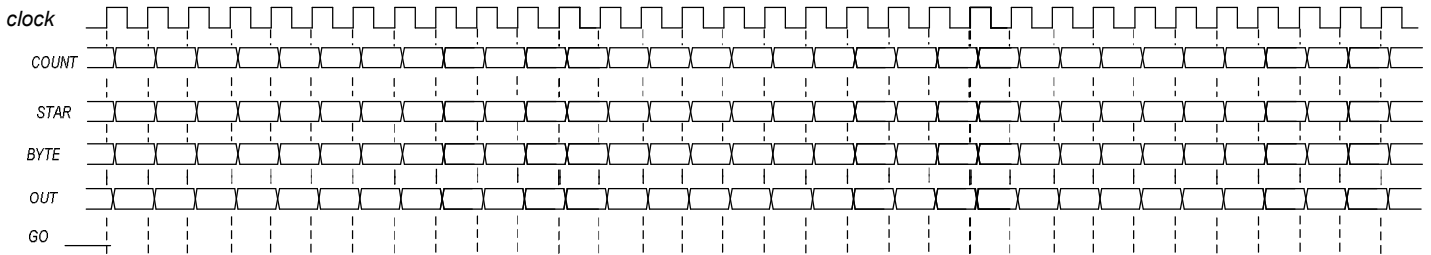
Service Name	Serv.No.(Sv0)	INPUT Arguments	OUTPUT Args	Service Name	Serv.No.(Sv0)	INPUT Arguments	OUTPUT Arguments
print int	1	\$a0=integer to print	---	read float	6	---	\$f0=float
print float	2	\$f12=float to print	---	read double	7	---	\$f0-fl=double
print double	3	(\$f12,\$f13)=double to print	---	read string	8	\$a0=address of input buffer, \$a1=max chars to read	---
print string	4	\$a0=address of ASCIIz string to print	---	sbrk	9	\$a0=Number of bytes to be allocated	\$v0=pointer to allocated memory
read int	5	---	\$v0=integer	exit	10	---	---

- 2) [5/30] Si consideri una cache di dimensione 320B e a 5 vie di tipo write-back/write-non-allocate. La dimensione del blocco e' 32 byte, il tempo di accesso alla cache e' 4 ns e la penalita' in caso di miss e' pari a 40 ns, la politica di rimpiazzamento e' LRU. Il processore effettua i seguenti accessi in cache, ad indirizzi al byte: 55, 173, 115, 119, 222, 947, 618, 449, 534, 748, 877, 919, 283, 143, 591, 644, 770, 845, 961, 194. Tali accessi sono alternativamente letture e scritture. Per la sequenza data, ricavare il tempo medio di accesso alla cache, riportare i tag contenuti in cache al termine, i bit di modifica (se presenti) e la lista dei blocchi (ovvero il loro indirizzo) via via eliminati durante il rimpiazzamento ed inoltre in corrispondenza di quale riferimento il blocco e' eliminato.
- 3) [4/30] Spiegare il funzionamento del FLIP-FLOP-D negative edge-triggered: riportare tabella della verita' e sintesi a livello di porte e per ogni riga della tabella della verita' dimostrare perché si ottiene quella data uscita usando il digramma temporale (in particolare per quanto riguarda la sensibilità sui fronti in discesa).
- 7) [10/30] Descrivere e sintetizzare l'Unità XXX che emette un byte generato in accordo alla legge di cui sotto. Il byte deve permanere all'uscita out di XXX per un numero di clock esattamente pari a numero_clock = byte * 2 e deve essere notificato (contestualmente alla presentazione del risultato in uscita) dal fatto che la variabile go passa da 0 ad 1 per un ciclo di clock. I byte generati soddisfano la condizione di essere numeri dispari. Tracciare il diagramma di temporizzazione come verifica della correttezza dell'unità XXX (il modulo Testbench e' riportato). Nota: si può svolgere l'esercizio su carta oppure con ausilio del simulatore salvando una copia dell'output (diagramma temporale) e del programma Verilog su USB-drive del docente.



```

module testbench;
    reg reset_; initial begin reset_=0; #22 reset_=1; #600; $stop; end
    reg clock; initial clock =0; always #5 clock <=!clock;
    wire[7:0] COUNT=XXX.COUNT;
    wire[7:0] BYTE =XXX.BYTE;
    wire      STAR =XXX.STAR;
    wire      go;
    wire[7:0] out;
    XXX Xxx(go,out, clock,reset_);
endmodule
    
```



SOLUZIONE

ESERCIZIO 1

```

.data
a: .word 51, 11, 32, 34, 11
   .word 51, 46, 5, 62, 27
sp: .asciiz " "

.globl main
.text
#-----
# a0=a, a1=n
t0=i, t1=j, t2=increm, t3=tmp
shellsort:
    addi $t8,$0,2 #costante=2
    div $a1,$t8 #n/2
    mflo $t2 #increm=(.)
ss_for1_ini:
    slt $t9,$0,$t2 #increm>?0
    beq $t9,$0,ss_for1_end
#-----for1 body start
    add $t0,$0,$t2
ss_for2_ini:
    slt $t9,$t0,$a1#i<?n
    beq $t9,$0,ss_for2_end
#-----for2 body start
    sll $t3,$t0,2 #i*4
    add $t3,$t3,$a0#&a[i]
    lw $t3,0($t3) #tmp=a[i]
    add $t1,$0,$t0 #j=i
ss_for3_ini:
    slt $t9,$t1,$t2#j<?increm
    bne $t9,$0,ss_for3_end
#-----for3 body start
    sub $t4,$t1,$t2#j-increm
    sll $t4,$t4,2 #(*)*4
    add $t4,$t4,$a0#&a[.]
    lw $t4,0($t4) #a[.]
    slt $t9,$t3,$t4#tmp<?(.)
    beq $t9,$0,ss_for1_end
#-----if body start
    sll $t5,$t1,2 #j*4
    add $t5,$t5,$a0#&a[j]
    sw $t4,0($t5) #a[j]=a[..]
    j ss_if_end
#-----if body_end
ss_if_end:
    j ss_for3_end #break
ss_if_end:
#-----for3 body end
    sub $t1,$t1,$t2#j--increm
    j ss_for3_ini
ss_for3_end:
    sll $t5,$t1,2 #j*4
    add $t5,$t5,$a0#&a[j]
    sw $t3,0($t5) #a[j]=tmp
#-----for2 body end
    addi $t0,$t0,1 #i++
    j ss_for2_ini
ss_for2_end:
#-----for1 body end
    div $t2,$t8 #increm/2
    mflo $t2 #increm=(.)
    j ss_for1_ini
ss_for1_end:
    jr $ra
#-----
main:
    la $a0,a # &a
    addi $a1,$0,10 # n
    jal shellsort
    add $t0,$0,$0 # i=0
main_forini:
    slt $t9,$t0,$a1# i<?n
    beq $t9,$0,main_forend
    sll $t2,$t0,2 # i*4
    la $t3,a # &a
    add $t2,$t2,$t3# &a[i]
    lw $a0,0($t2) # a[i]
    addi $v0,$0,1 # serv.1
    syscall
    la $a0,sp # &sp
    addi $v0,$0,4 # serv.4
    syscall
    addi $t0,$t0,1 #i++
    j main_forini
main_forend:
    addi $v0,$0,10 # serv.10
    syscall

```

Console
5 11 11 27 32 34 46 51 51 62

ESERCIZIO 2

Sia X il generico riferimento, A=associativita', B=dimensione del blocco, C=capacita' della cache.

Si ricava S=C/B/A=# di set della cache=320/32/5=2, XM=X/B, XS=XM%S, XT=XM/S:

A=5, B=32, C=320, RP=LRU, Thit=4, Tpen=40, 20 references:

===	T	X	XM	XT	XS	XB	H	[SET]:USAGE	[SET]:MODIF	[SET]:TAG
===	R	55	1	0	1	23	0	[1]:4,0,0,0,0	[1]:0,0,0,0,0	[1]:0,-,-,-,-
===	W	173	5	2	1	13	0	[1]:3,4,0,0,0	[1]:0,0,0,0,0	[1]:0,2,-,-,-
===	R	115	3	1	1	19	0	[1]:2,3,4,0,0	[1]:0,0,0,0,0	[1]:0,2,1,-,-
===	W	119	3	1	1	23	1	[1]:2,3,4,0,0	[1]:0,0,1,0,0	[1]:0,2,1,-,-
===	R	222	6	3	0	30	0	[0]:4,0,0,0,0	[0]:0,0,0,0,0	[0]:3,-,-,-,-
===	W	947	29	14	1	19	0	[1]:1,2,3,4,0	[1]:0,0,1,0,0	[1]:0,2,1,14,-
===	R	618	19	9	1	10	0	[1]:0,1,2,3,4	[1]:0,0,1,0,0	[1]:0,2,1,14,9
===	W	449	14	7	0	1	0	[0]:3,4,0,0,0	[0]:0,0,0,0,0	[0]:3,7,-,-,-
===	R	534	16	8	0	22	0	[0]:2,3,4,0,0	[0]:0,0,0,0,0	[0]:3,7,8,-,-
===	W	748	23	11	1	12	0	[1]:4,0,1,2,3	[1]:0,0,1,0,0	[1]:11,2,1,14,9
===	R	877	27	13	1	13	0	[1]:3,4,0,1,2	[1]:0,0,1,0,0	[1]:11,13,1,14,9
===	W	919	28	14	0	23	0	[0]:1,2,3,4,0	[0]:0,0,0,0,0	[0]:3,7,8,14,-
===	R	283	8	4	0	27	0	[0]:0,1,2,3,4	[0]:0,0,0,0,0	[0]:3,7,8,14,4
===	W	143	4	2	0	15	0	[0]:4,0,1,2,3	[0]:0,0,0,0,0	[0]:2,7,8,14,4
===	R	591	18	9	0	15	0	[0]:3,4,0,1,2	[0]:0,0,0,0,0	[0]:2,9,8,14,4
===	W	644	20	10	0	4	0	[0]:2,3,4,0,1	[0]:0,0,0,0,0	[0]:2,9,10,14,4
===	R	770	24	12	0	2	0	[0]:1,2,3,4,0	[0]:0,0,0,0,0	[0]:2,9,10,12,4
===	W	845	26	13	0	13	0	[0]:0,1,2,3,4	[0]:0,0,0,0,0	[0]:2,9,10,12,13
===	R	961	30	15	0	1	0	[0]:4,0,1,2,3	[0]:0,0,0,0,0	[0]:15,9,10,12,13
===	W	194	6	3	0	2	0	[0]:3,4,0,1,2	[0]:0,0,0,0,0	[0]:15,3,10,12,13

CONTENTUTI dei 5 SET al termine:

LISTA BLOCCHI USCENTI:

- (out: XM=1 XT=0 XS=1)
- (out: XM=5 XT=2 XS=1)
- (out: XM=6 XT=3 XS=0)
- (out: XM=14 XT=7 XS=0)
- (out: XM=16 XT=8 XS=0)
- (out: XM=28 XT=14 XS=0)
- (out: XM=8 XT=4 XS=0)
- (out: XM=4 XT=2 XS=0)
- (out: XM=18 XT=9 XS=0)

P1 Nmiss=19 Nhit=1 Nref=20 mrate=0.950000 AMAT=th+mrate*tpen=42

ESERCIZIO 3

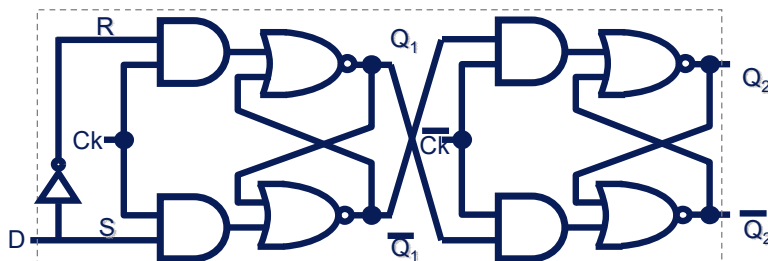
Quando CK=1, il master Clocked-SR latch e' trasparente e lo slave e' opaco. Quindi il valore di D si propaga su Q1. Quando CK=0, il master diventa opaco e lo slave trasparente: il valore di Q1 si propaga su Q, ma Q1 resta scollegato da D. QUINDI: qualunque valore sia presente su D un momento PRIMA del fronte in discesa del clock da 1 a 0, tale valore di D viene copiato su Q immediatamente DOPO la discesa del clock. In tutti gli altri momenti Q mantiene il suo vecchio valore, perche' c'e' sempre un Clocked-SR latch opaco che blocca il cammino da D a Q.

FLIP FLOP D negative edge triggered

In questo caso vogliamo sensibilita' solo sul fronte in discesa

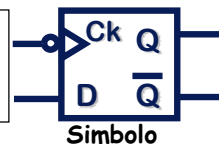
D	Ck	Q
X	1	Q
X	0	Q
X	↓	Q
0	↓	0
1	↓	1

Tabella di Verità

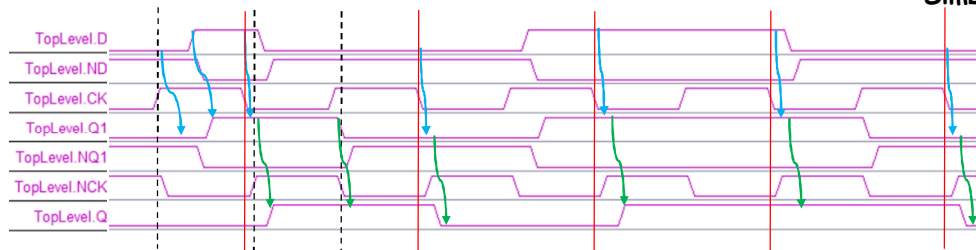


Schema logico a livello di porte

Layout simbolico: 44 transistor
 =4*NAND+4*(NAND+NOT)+ 2 per /Ck
 + 2 per la not su D =4*16+4*(4+2)+2+2



Simbolo



ESERCIZIO 7

Codice VERILOG:

```

module XXX(go,out, clock,reset_); //uso modello Mealy-Ritardato
input      clock, reset_;
output     go;
output [7:0] out;                //go,out fanno le veci di 'z'

reg STAR; parameter S0=0,S1=1;   //STAR,COUNT,BYTE: definizione stato
reg [7:0] COUNT;                //
reg [7:0] BYTE;                 //

reg        GO; assign go=GO;     //GO,OUT fanno le veci di 'OUTR'
reg [7:0]  OUT; assign out=OUT;  //

wire[7:0]  new_byte      = (BYTE==0)?1:(BYTE+2); //legge f(X,S)
wire[7:0]  numero_clock  = BYTE*2;             //(X in questo caso non c'è)

always @(reset_==0) begin STAR=S0; GO<=0; BYTE<=0; COUNT<=3; OUT<=0; end //RESET

always @(posedge clock or negedge reset_) if (reset_==1) #0 //evoluzione degli stati
  casex (STAR)
    S0: begin if (BYTE>0) GO<=1; COUNT<=(COUNT-1); OUT<=BYTE; BYTE<=new_byte; STAR<=S1; end
    S1: begin GO<=0; COUNT<=(COUNT==1)?numero_clock:(COUNT-1); STAR<=(COUNT==1)?S0:S1; end
  endcase

endmodule
    
```

Diagramma temporale:

