“FEUPAutom_Grafcet”

(incluindo Grafcet hierárquico e comparação com norma)

Armando Sousa

27/04/2020

FEUPAutom5
(SoftPLC | Grafcet+ST | ModbusTCP | Cross-Platform)
Code: Armando Jorge Sousa, Bruno Augusto and Paulo Costa

Historico da UC

Sistemas de Máquinas de Estados (SME)

Implementação (Manual) de SMEs
(Arduino, PC e FEUAutom)

Grafcet

Norma IEC 60848

Implementação de Grafcet (FEUPAutom)

Implementação manual de Grafcet sob Arduino e PC

FEUPAutom

- SoftPLC
  - Software que emula um PLC dentro de um PC comum

FEUPAutom

- SoftPLC
  - Software que emula um PLC dentro de um PC comum
- Executa código ST
- Comunica com simulações e dispositivos reais
- *Debugging* fácil
  - Inspeção de variáveis
  - Traçados temporais
  - Em Grafcet mostra etapas ativas

FEUPAutomGrafcet

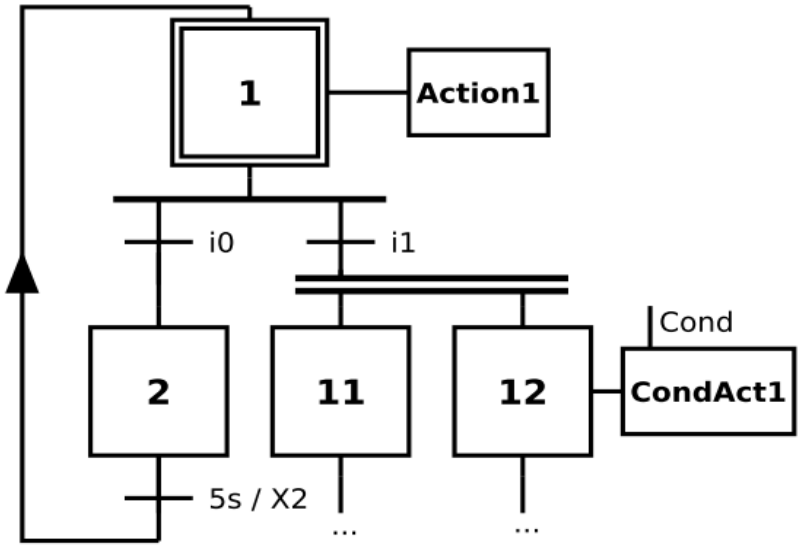
- Editor gráfico de “Grafcet”
- Execução local instantânea com *debug* fácil
- Traduz (*oneway*) de “Grafcet” para ST
  - Útil se não tivermos disponível um compilador
- Na versão >=4, compila para C (sob AVRGCC)

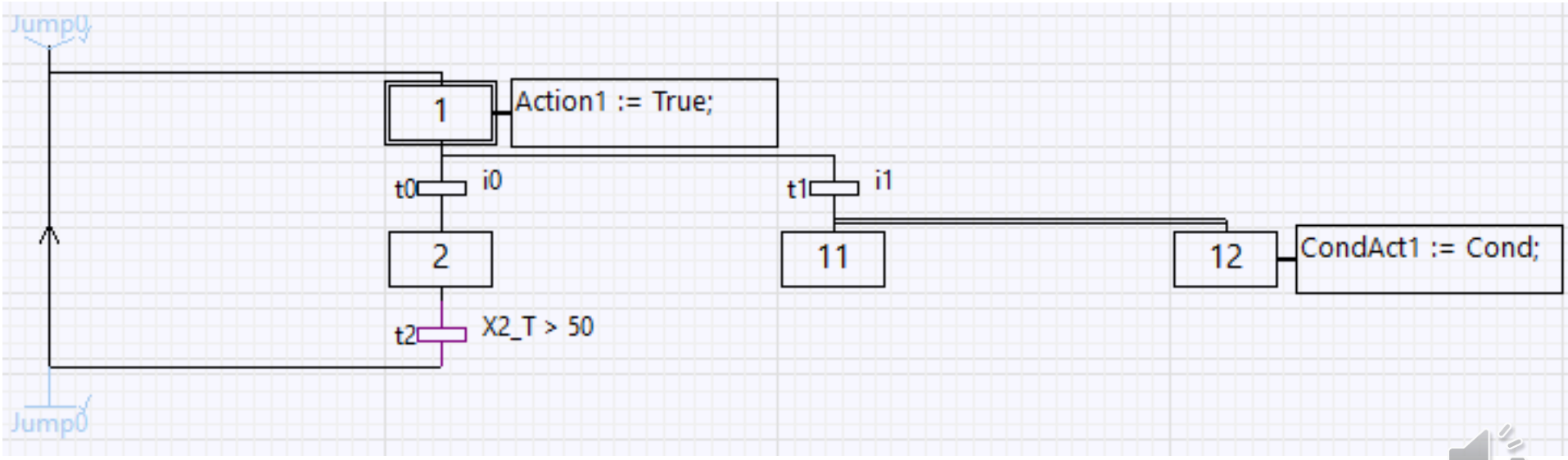
- Utiliza o algoritmo Síncrono –
  – com adaptações
  - daí “FEUPAutomGrafcet”

FEUPAutomGrafcet

Norma => Declarativa

FEUPAutom => Imperativa





Alg. Genérico Síncrono

2. Se Início (Cold_Boot) =>
   => Ativar etapas iniciais

3. Calcular
   Transições Disparadas (TrD)

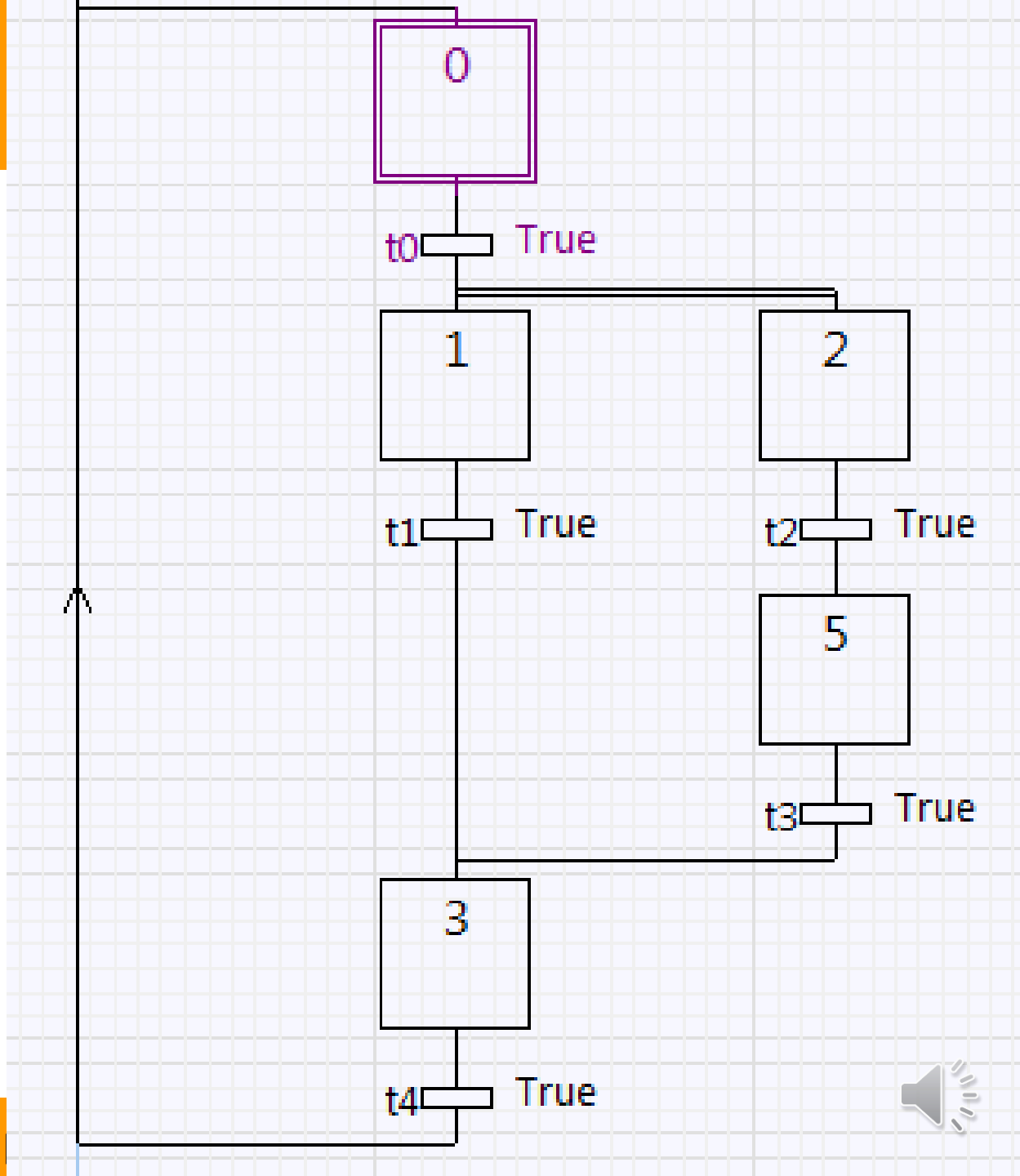
4. Para as TrDs,
   desligar etapas a montante

5. Para as TrDs,
   ligar etapas a jusante

8. Ativar as saídas de
   acordo com as Etapas Ativas

Alg. Genérico Síncrono	FEUPAutomGrafcet
	*** *Para cada Página, da P3 para a P0 (tendo em conta os Hooks)*
2. Se Início (Cold_Boot) => => Ativar etapas iniciais	2.Se (Cold_Boot) => => Ativar etapas iniciais
3. Calcular Transições Disparadas (TrD)	3. Se (não Cold_Boot) => => Calc. Transições Disparadas (TrD)
4. Para as TrDs, desligar etapas a montante	4. Para as TrDs, desligar etapas a montante
5. Para as TrDs, ligar etapas a jusante	5. Para as TrDs, ligar etapas a jusante + ini. temporizad.
	6. (Opcionalmente) Desligar todas saídas
	7. Cada 1/10 de seg. para Etapas Ativas=> => Incrementar temporiz. dessa Etapa
8. Ativar as saídas de acordo com as Etapas Ativas	8. Para Etapas Ativas => Executar ação

Caso de Estudo

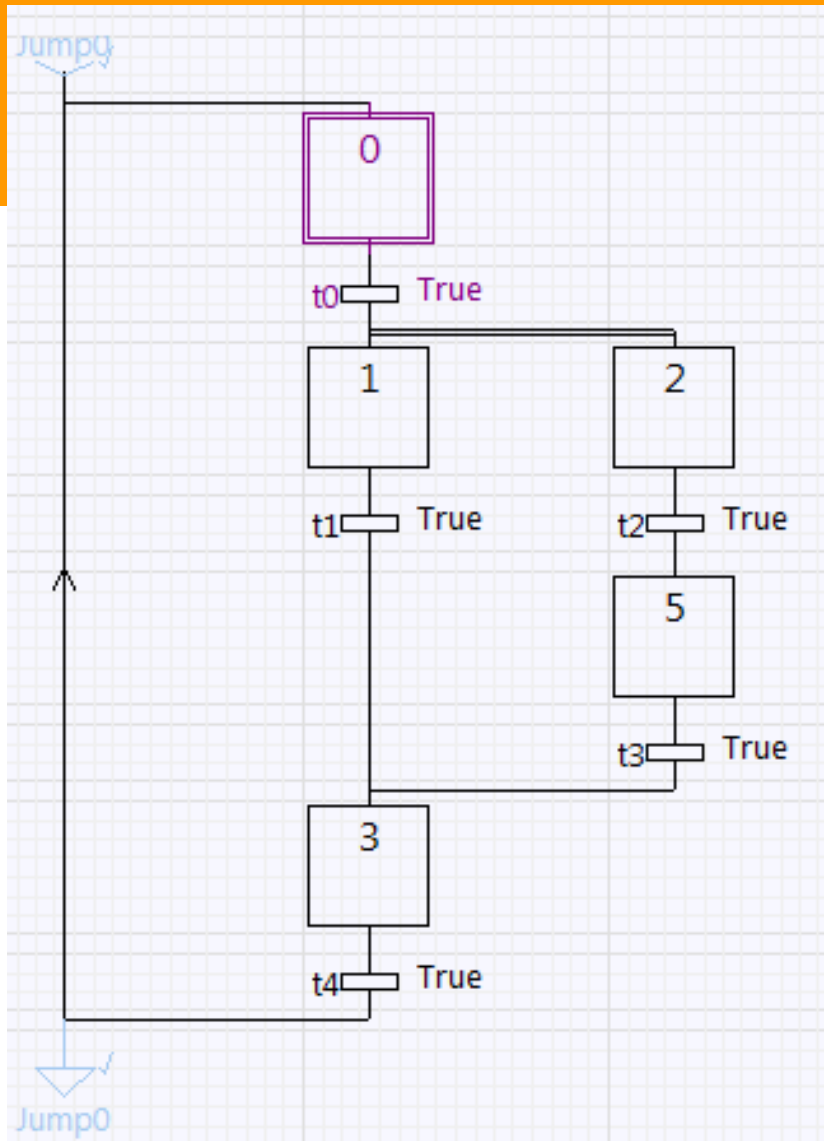


Evolução temporal
(saudável)

Evolução Temporal exemplo:
(reset)

- {0} => disparando t0 =>
- {1,2} => disparando t3+t5 =>
- {3,5} => disparando t2+t4 =>
- {0,3} => disparando t0+t4 =>
- {0,1,2} ...

(até é possível todas
as etapas ficarem ativas!)



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Evolução Temporal exemplo:
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- {0,1,2} ...

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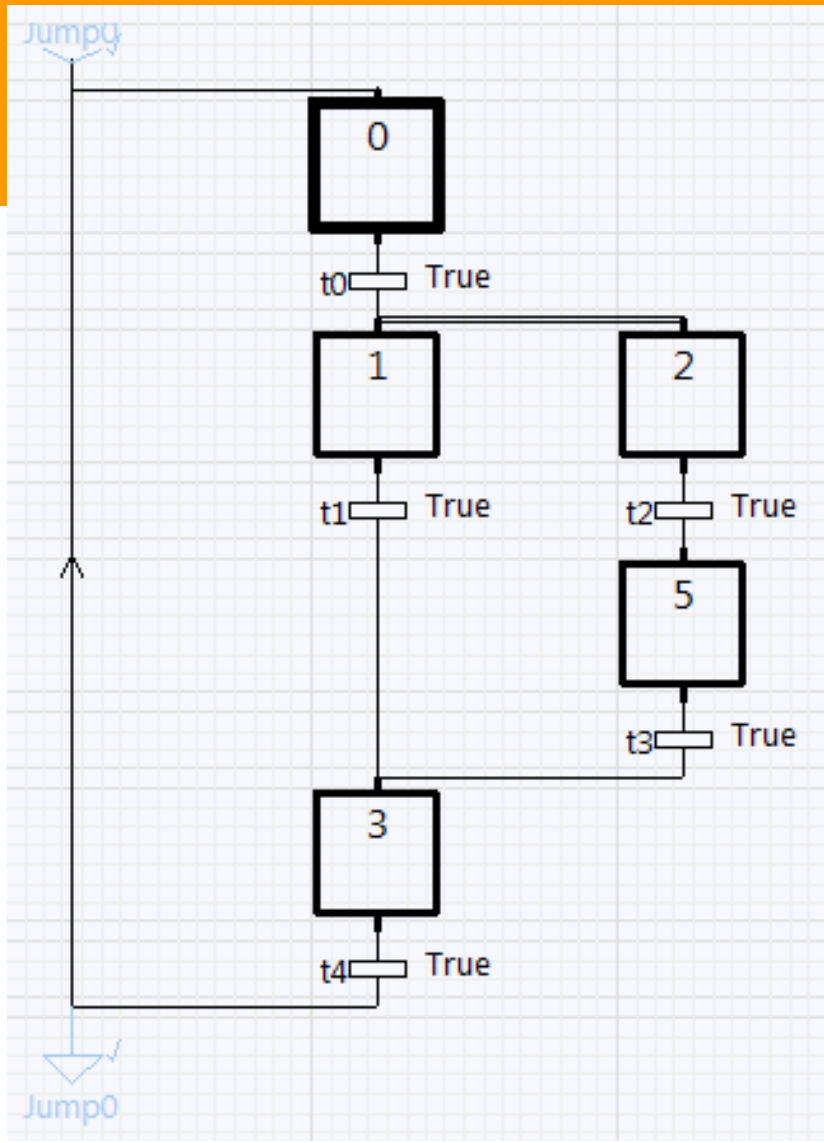
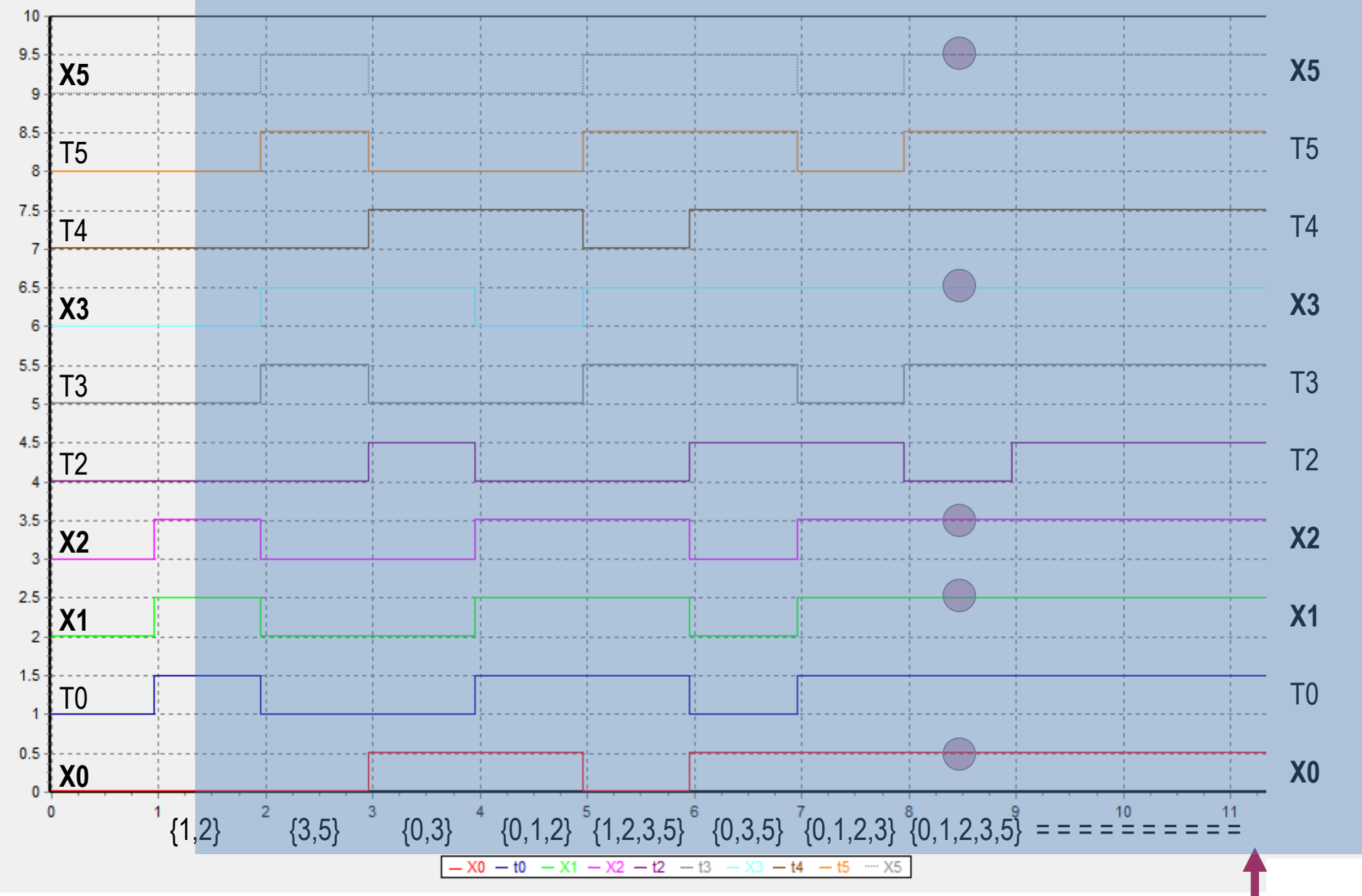
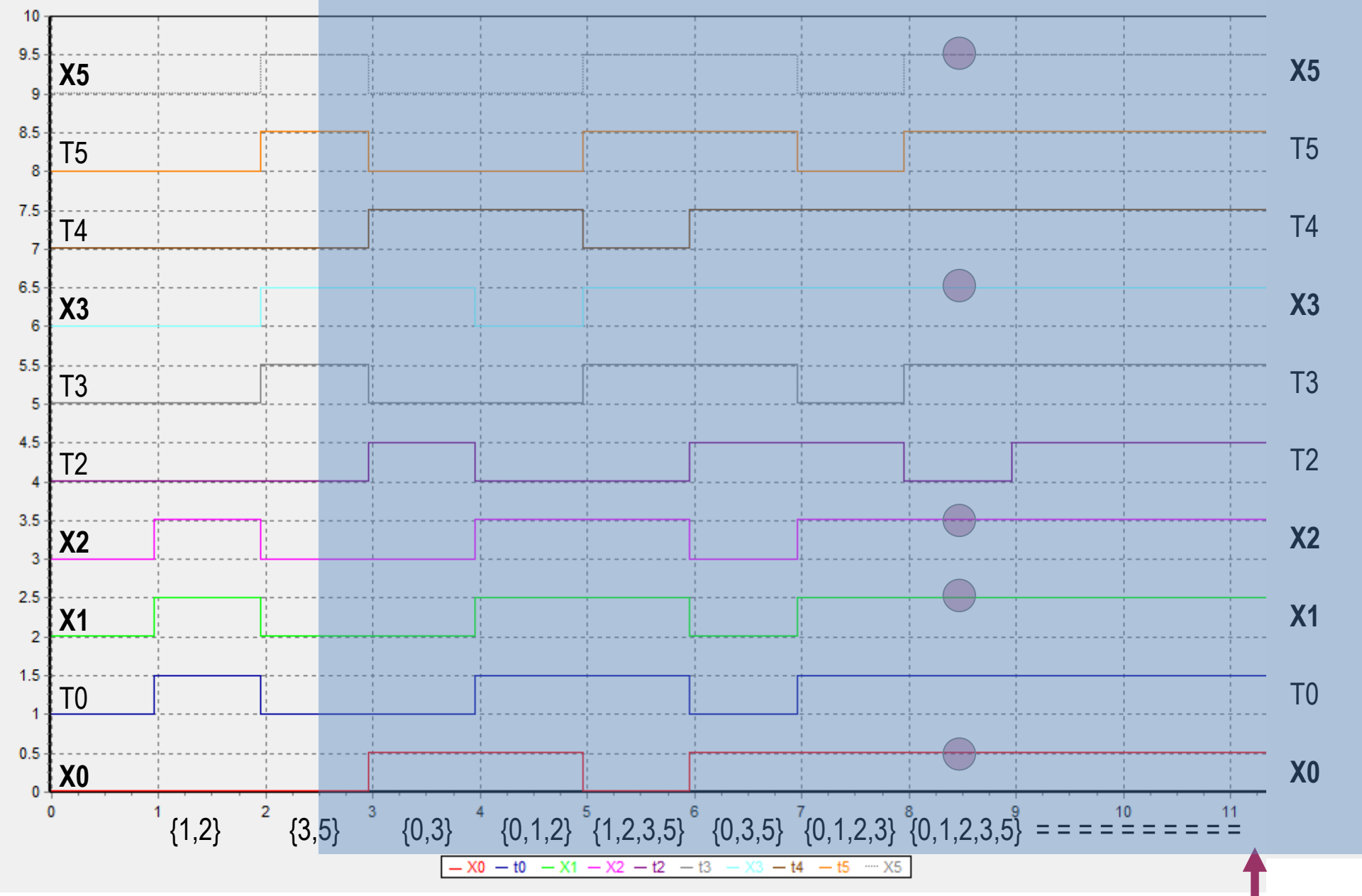




(1 segundo por ciclo) Todas as etapas ligadas...



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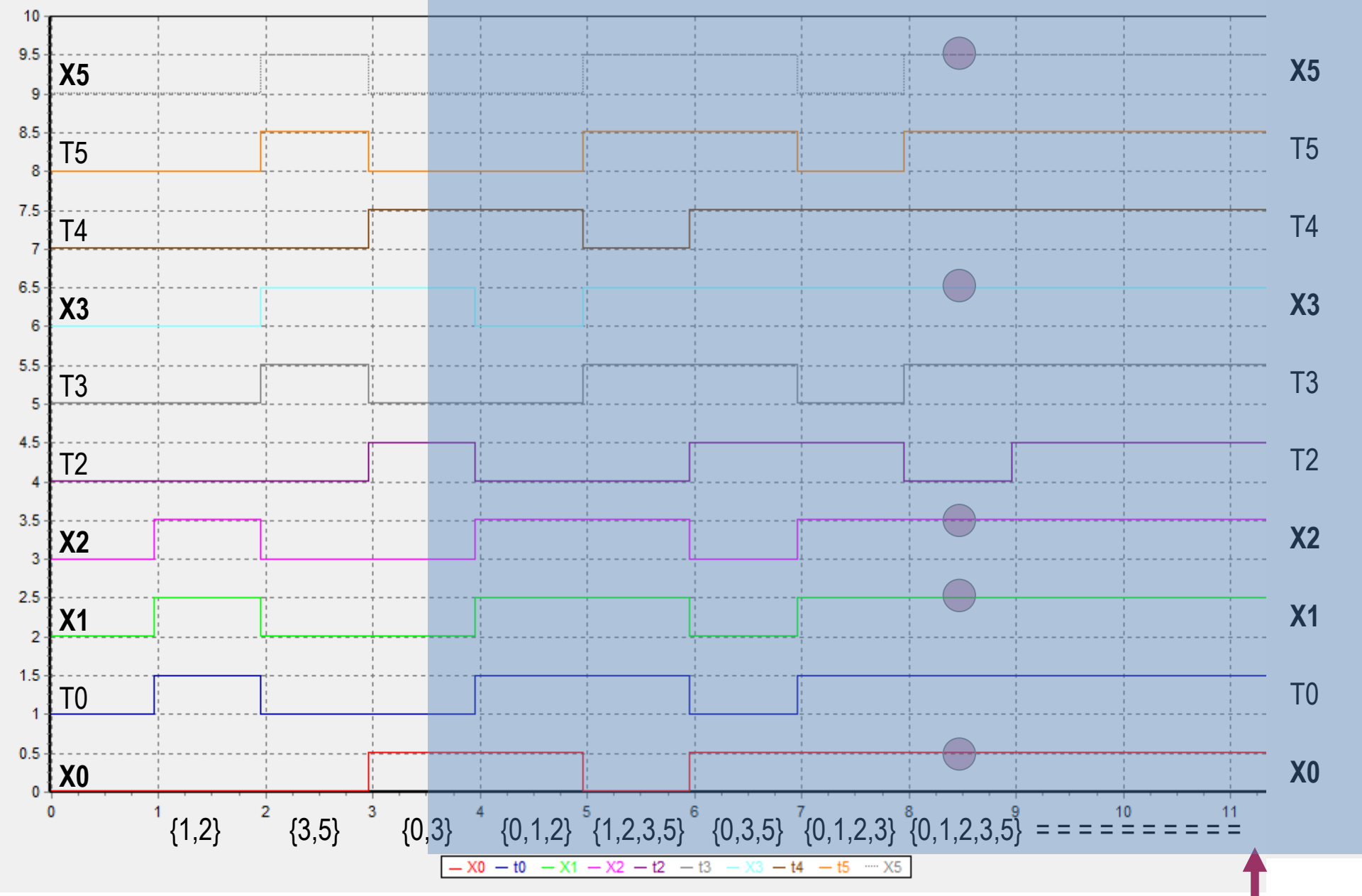

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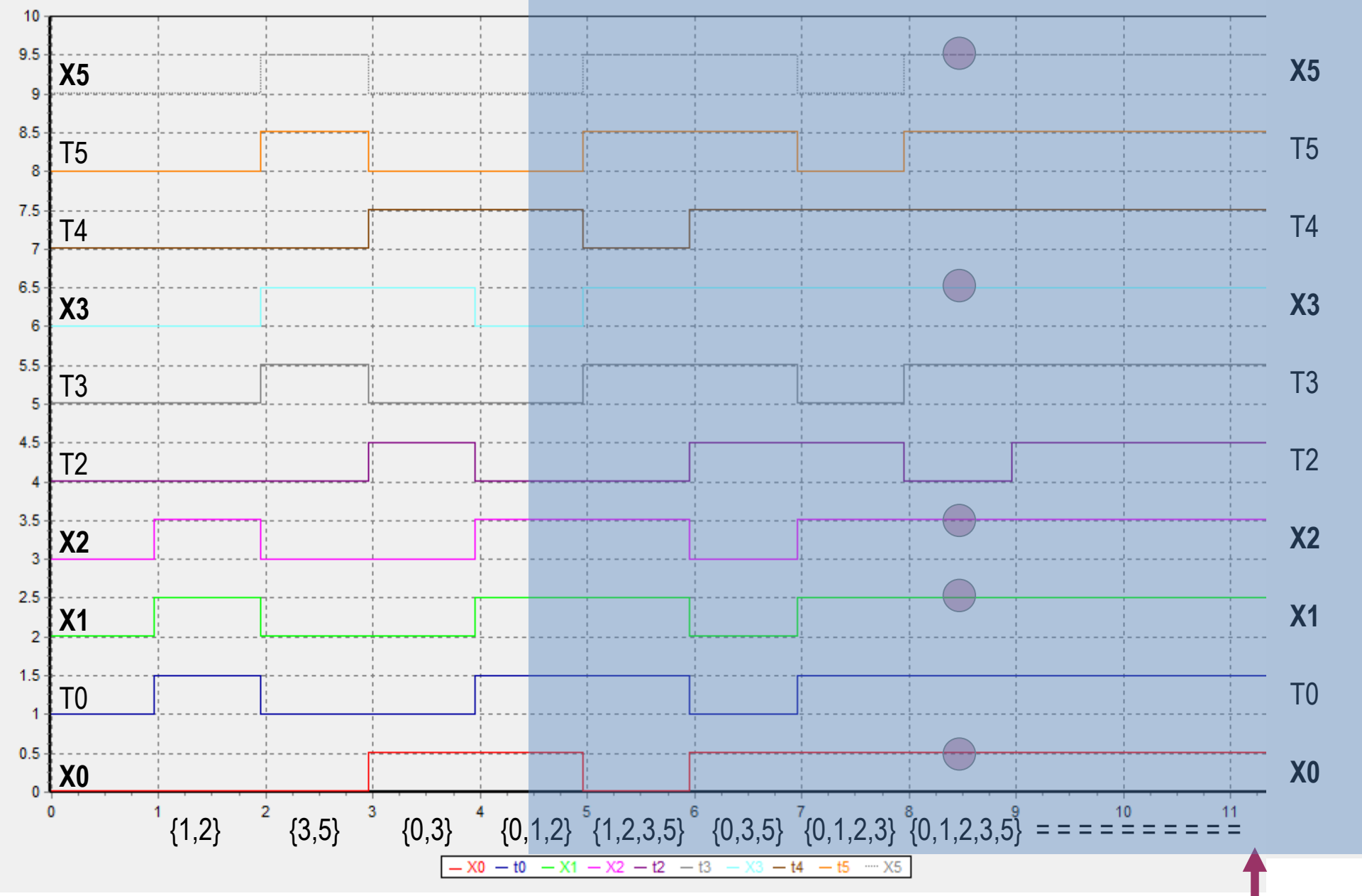

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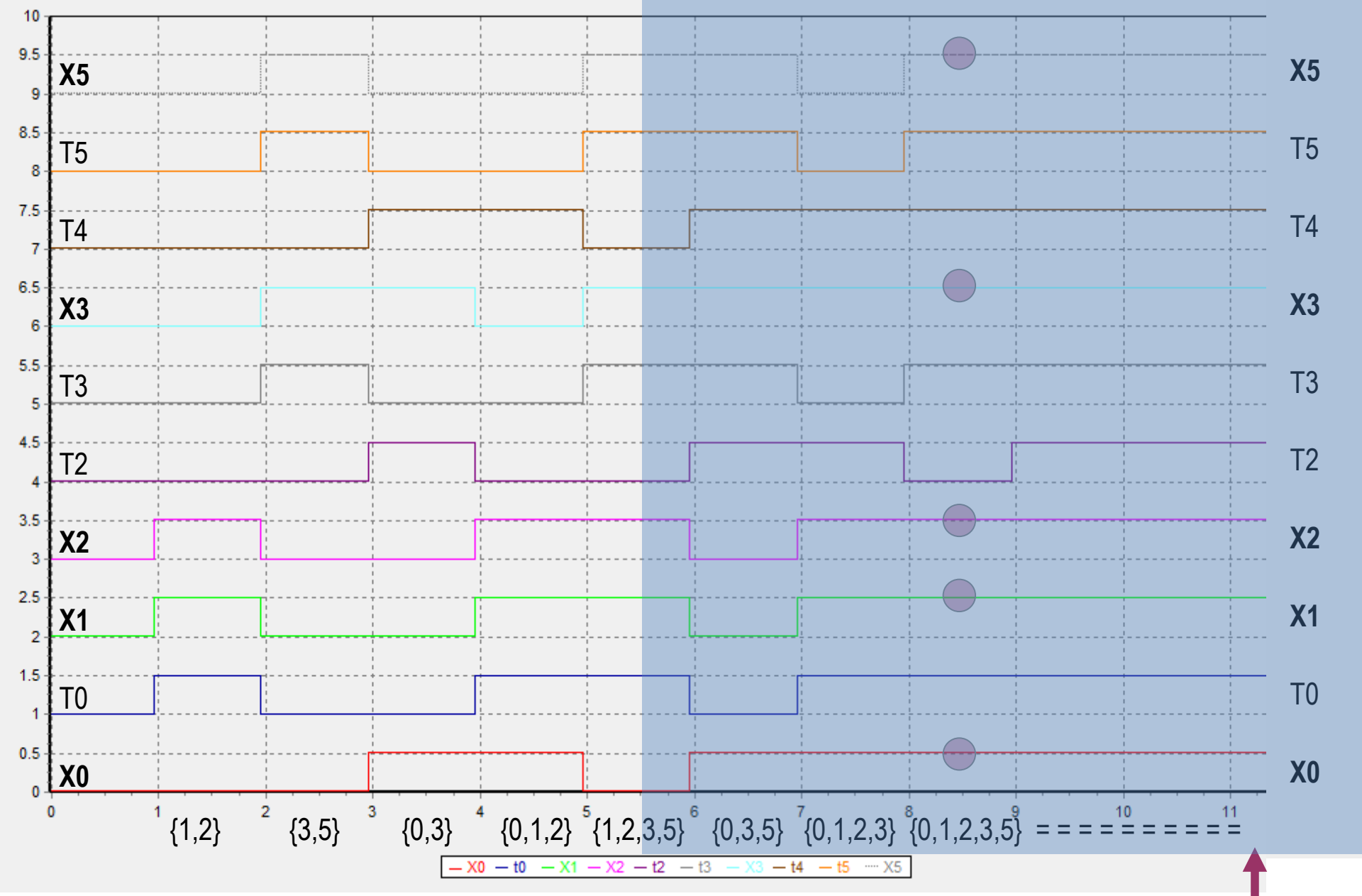

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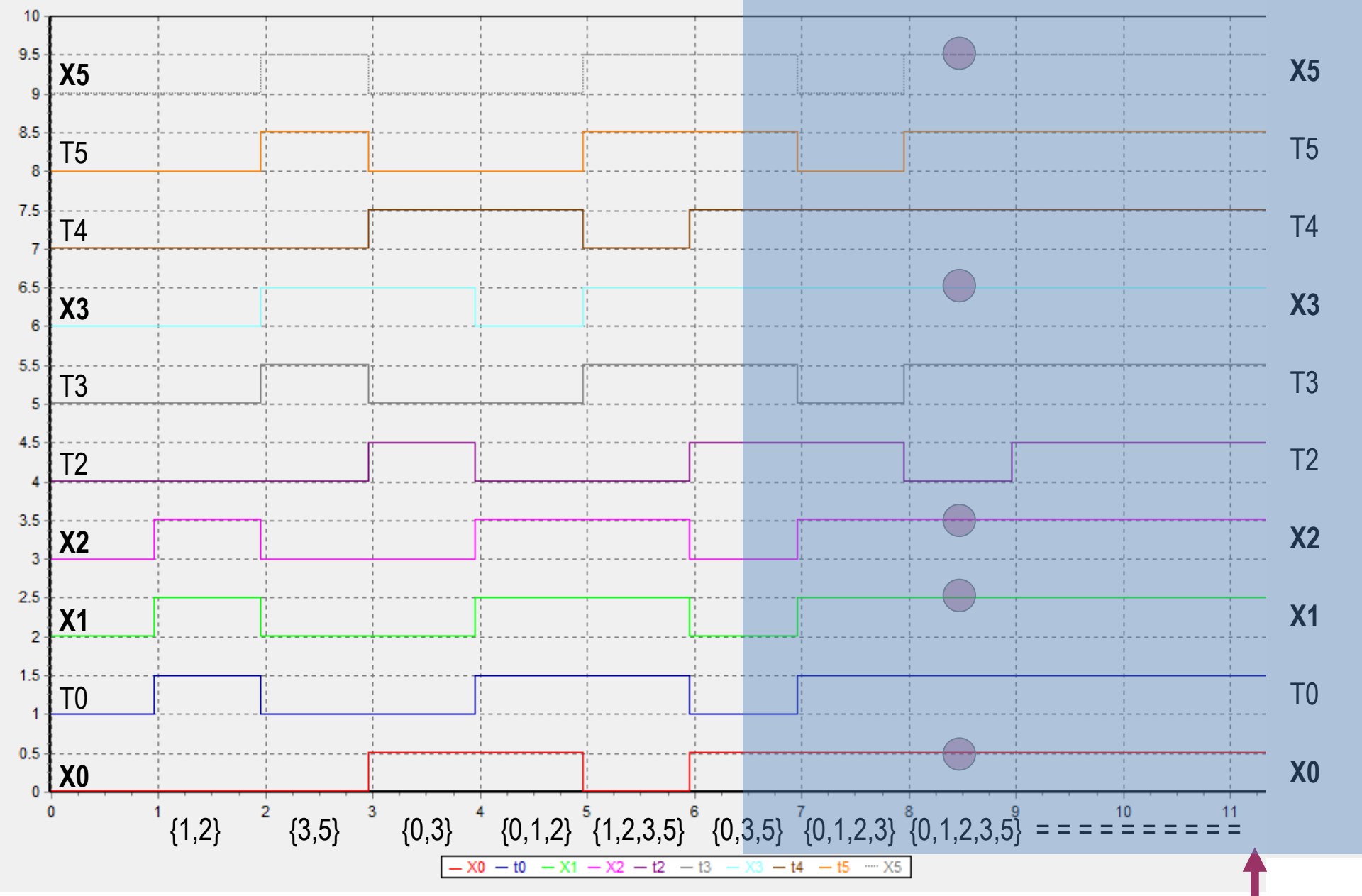

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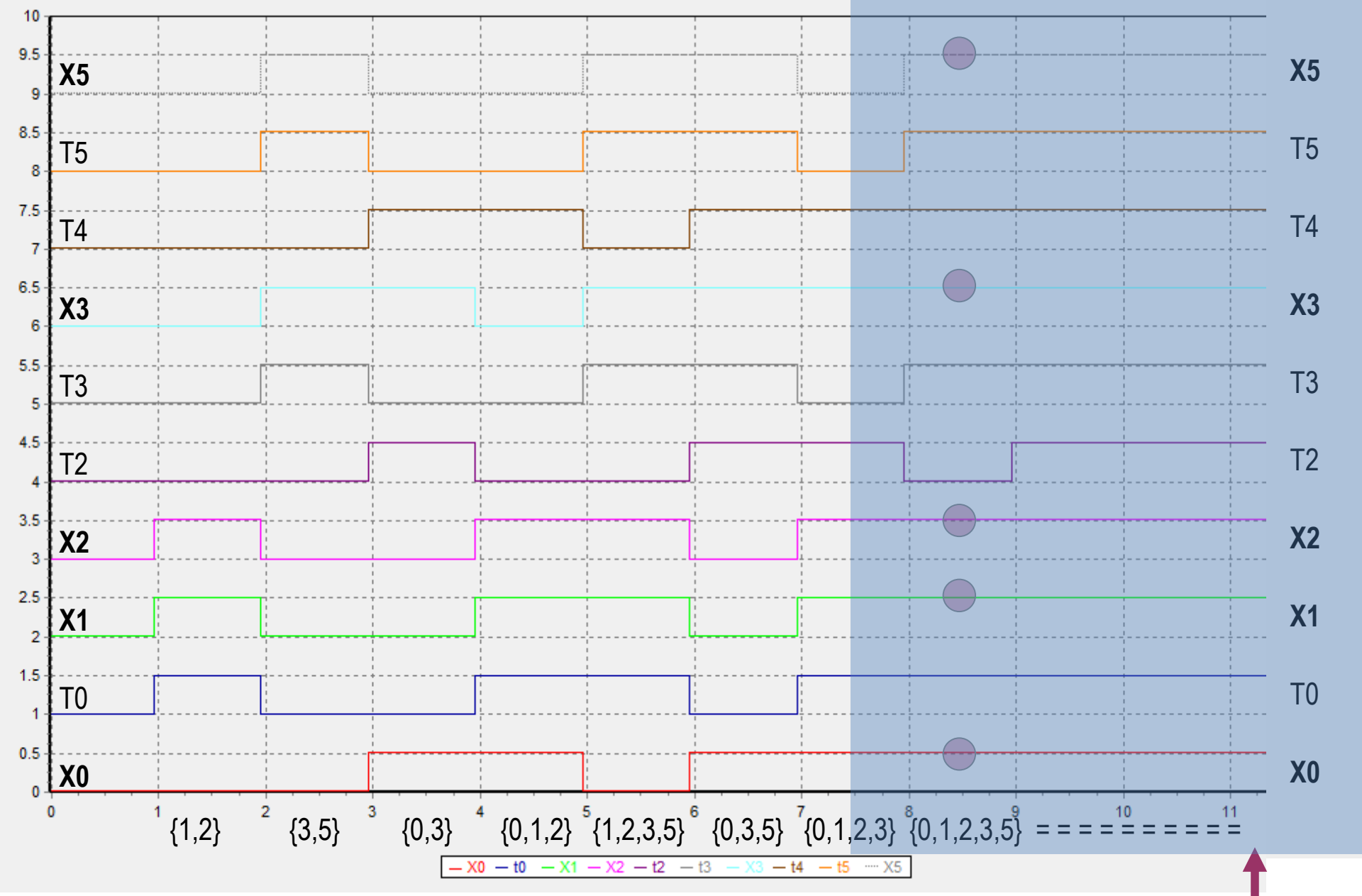

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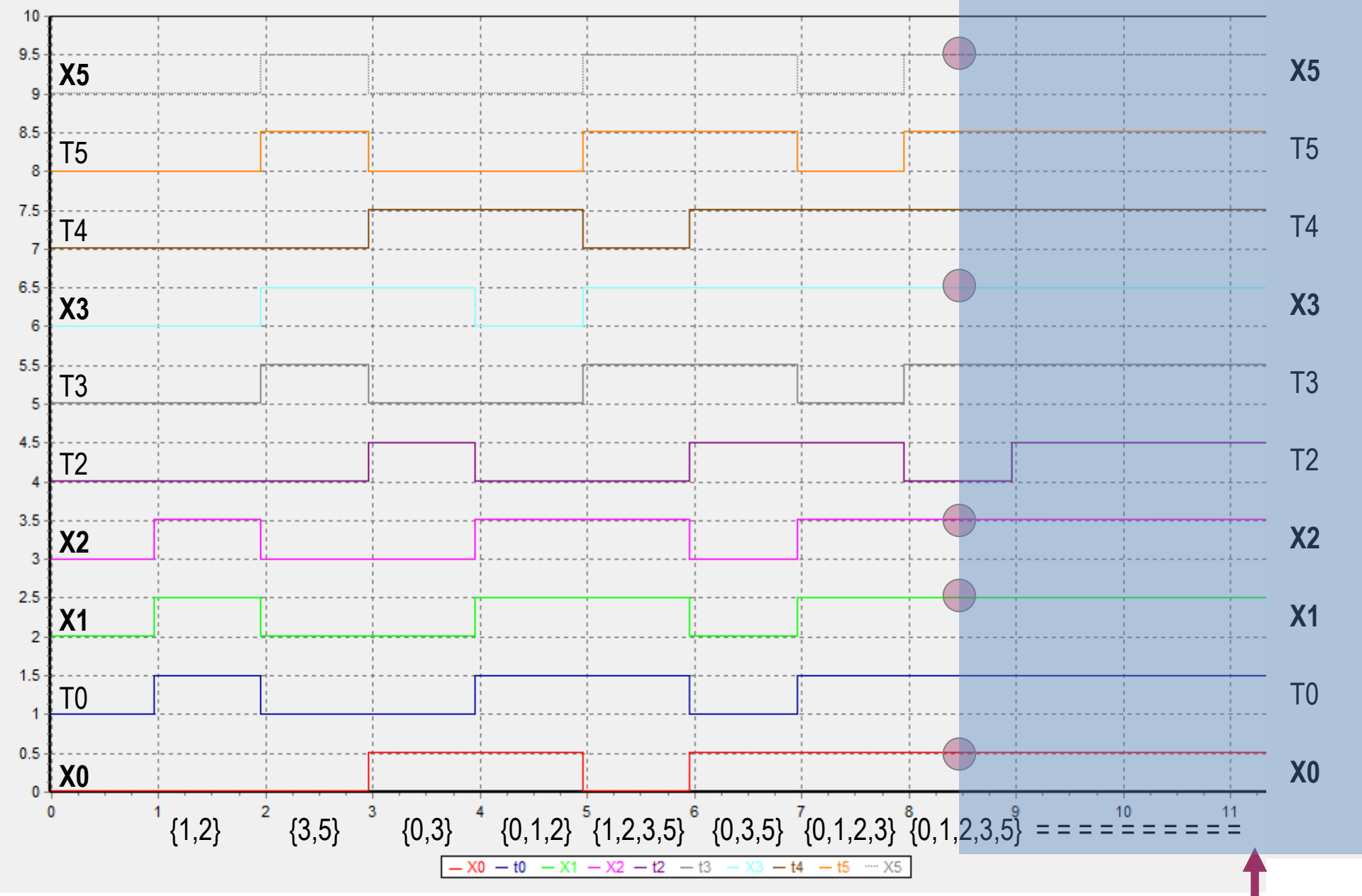


(1 segundo por ciclo) Todas as etapas ligadas...

Limitações FEUPAutomGrafcet

Obs:

O algoritmo apresentado permite alguma hierarquia (entre páginas)

porém não permite … um Grafcet congelar outro ☹ !

=> Transições "congeladas" por página

=> Daí a necessidade dos hook's ("Zones")

FEUPAutom - Control Cycle

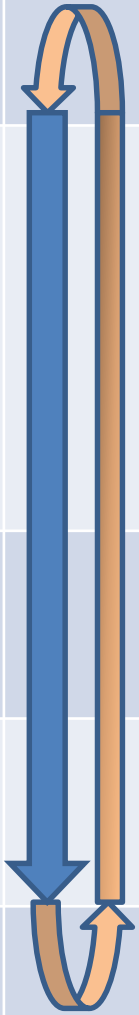
Read from Physical Inputs
to Memory Variables

Execution of Script -
FEUPAutom / FEUPAutomGrafcet
(detailed next)

Write to Physical Outputs
from Memory Variables

Internal Processing

Operating System (Windows/…)



All
Processing
is done
on memory
variables

FEUPAutomGrafcet

Zones

*** Repetir da Página 3 à Página 0 ***

Se (Cold_Boot) => Ativar etapas iniciais

Se (não Cold_Boot) => Calc. Trans. Disparadas (TrD)

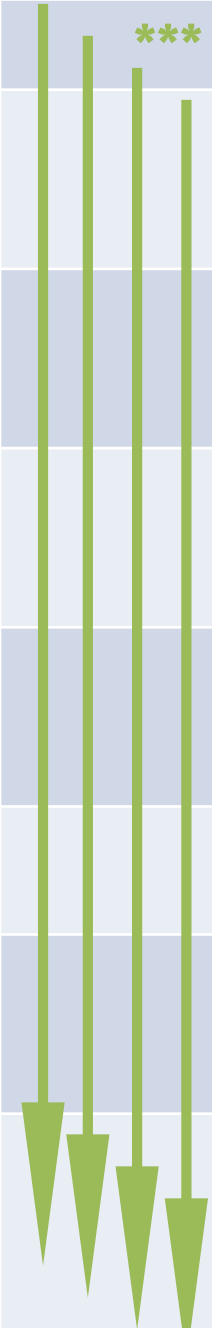
Para as TrDs, desligar etapas a montante

Para as TrDs, ligar etapas a jusante + ini. temporizad.

Se (Página_P3) => Desligar todas saídas

Cada 1/10 de seg. para Etapas Ativas=>
=> Incrementar temporiz. dessa Etapa

Para Etapas Ativas => Executar ação



"Zone1"

"Zone2"

"Zone3"

"Zone4"

"Zone5"

"Zone6"

"Zone7"

"Zone8"

“Compilar”

- Criar variáveis com nomes certos
  - 1 bit / transição (t_i)
  - 1 bit / etapa (x_j)
  - 1 word / etapa (x_j_T)
- Para cada Transição
  (tendo em consideração saltos)
  - Congelamento por página
  - Listar etapas a montante
  - Listar etapas a jusante
- Gerar efetivamente o código ☺

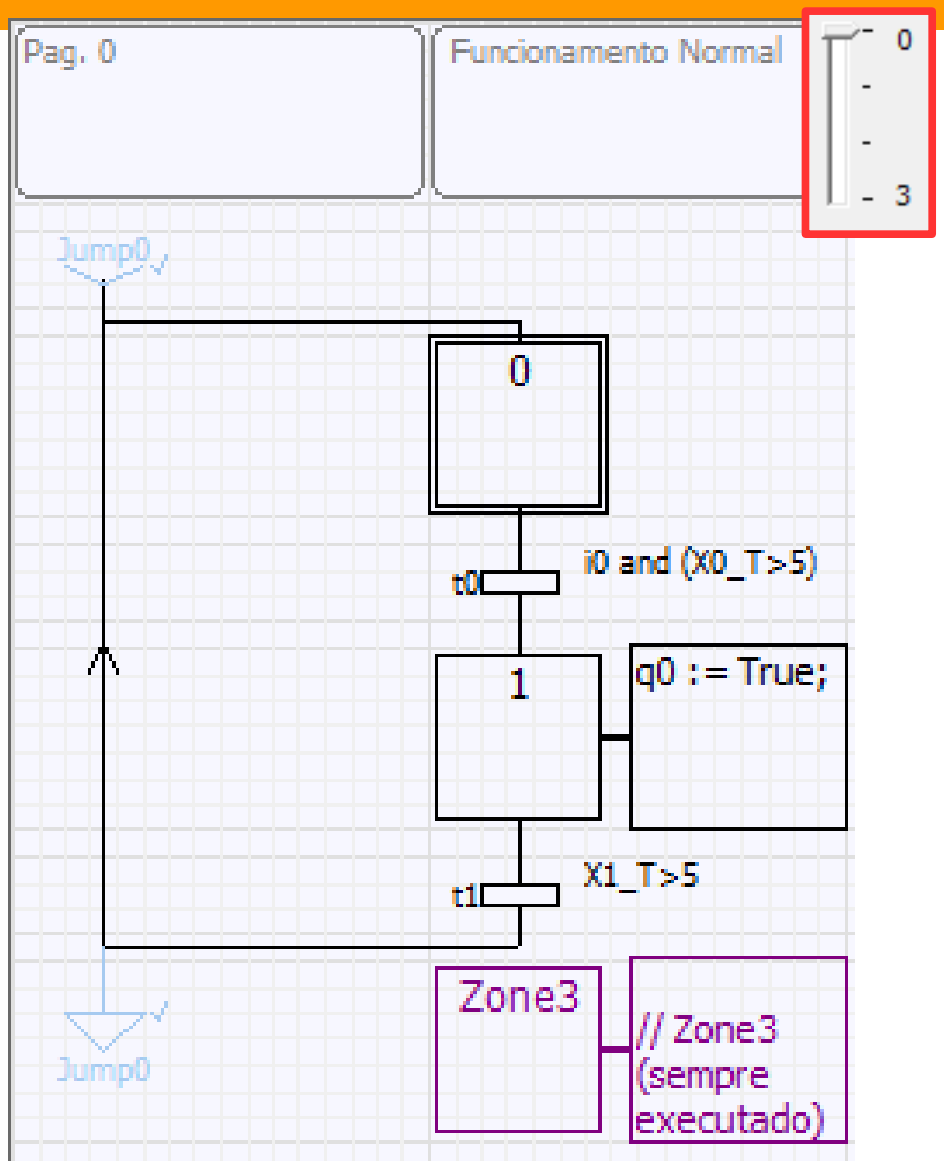
Atenção: é possível utilizar variáveis auxiliares
mas não devem estar em conflito com o Grafcet

Limitações FEUPAutomGrafcet

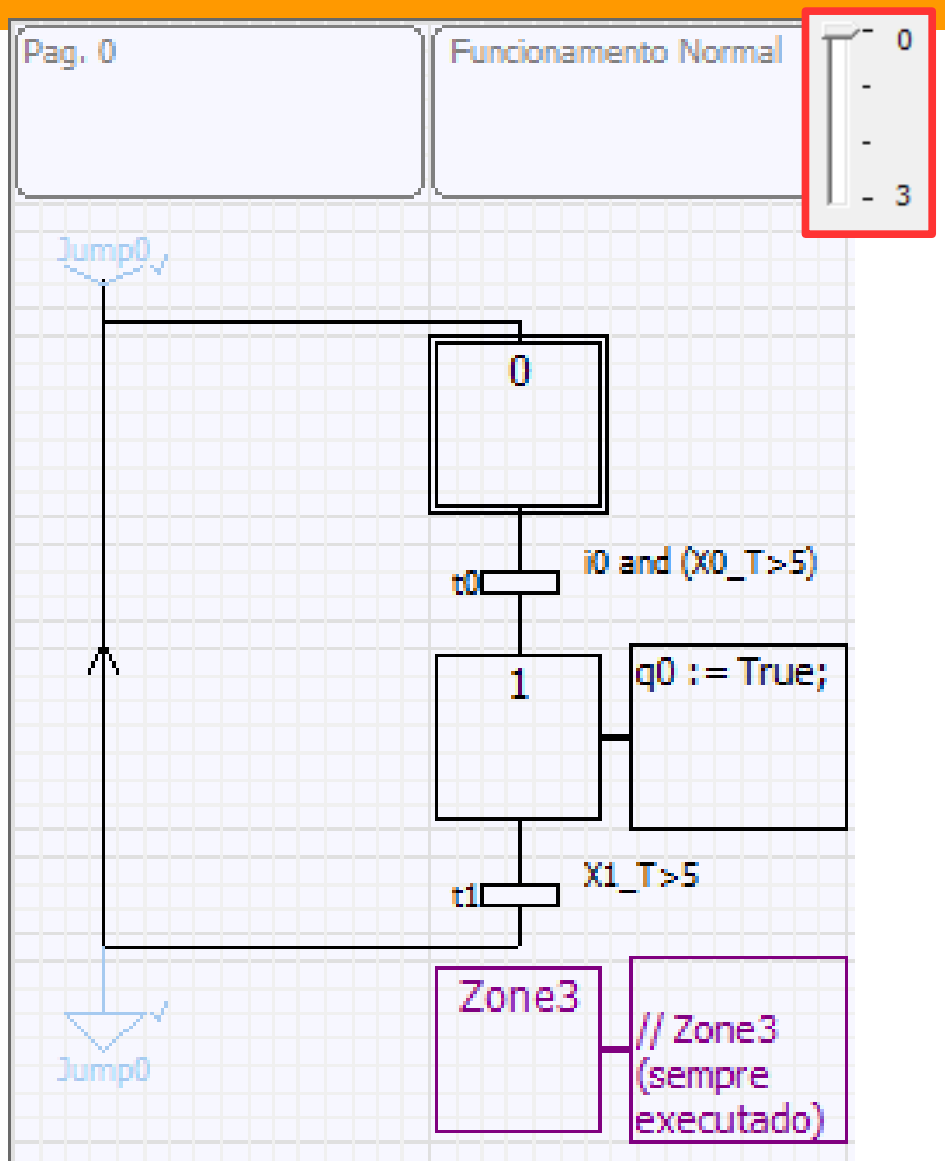
Com estes hooks, é possível “congelar” uma parte do Grafcet com código na “Zone ??? ” ☺

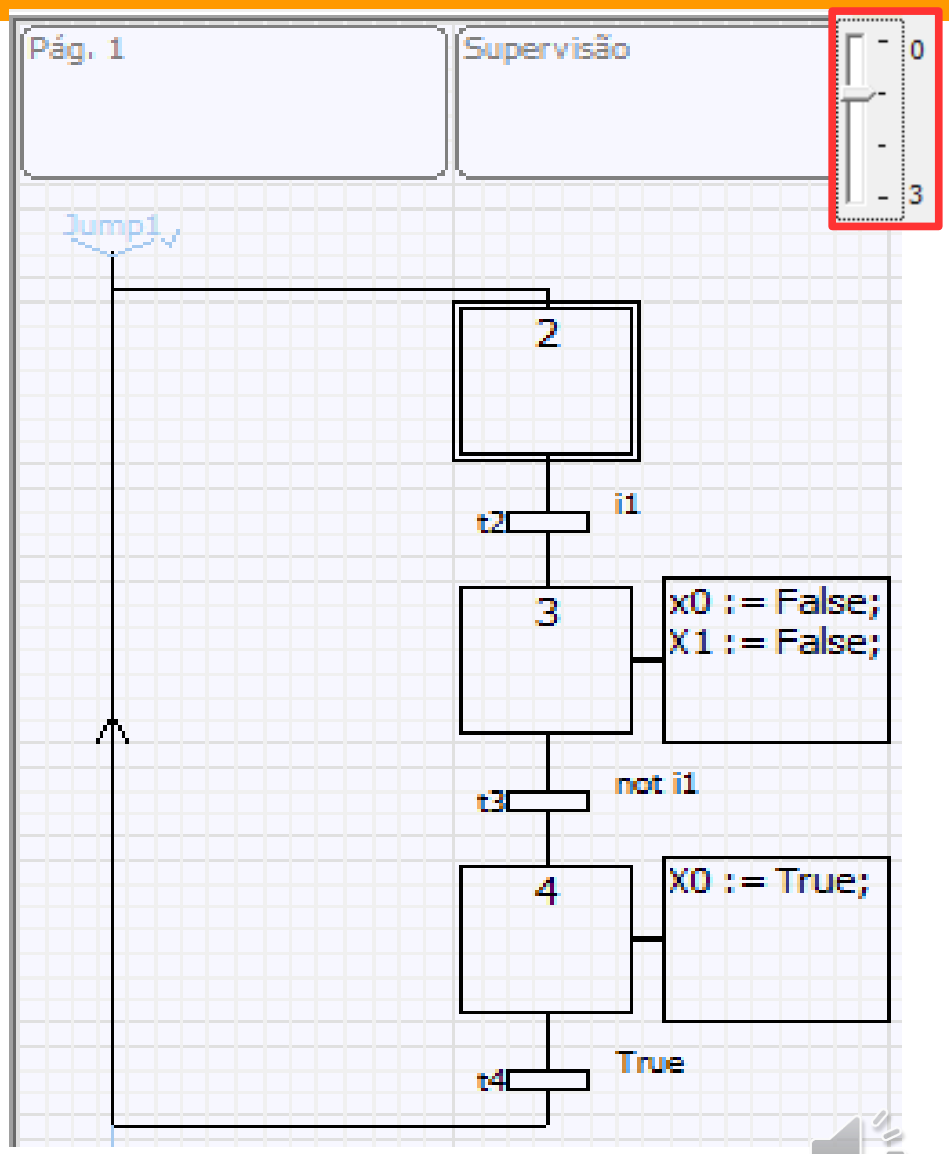
Com estes hooks, é possível escrever verificações de segurança ao código na “Zone ??? ” ☺

Páginas (próximo de hierarquia)

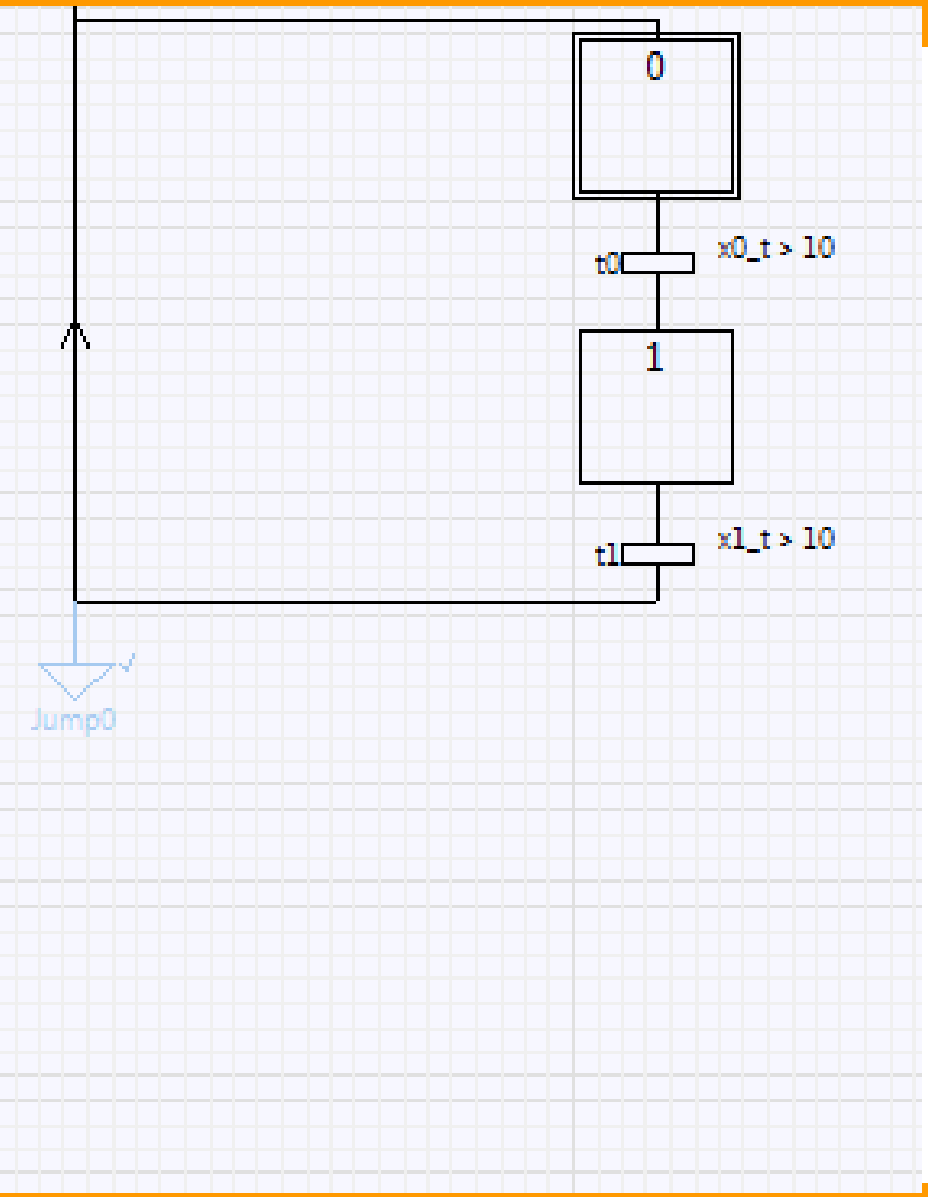


Páginas (próximo de hierarquia)



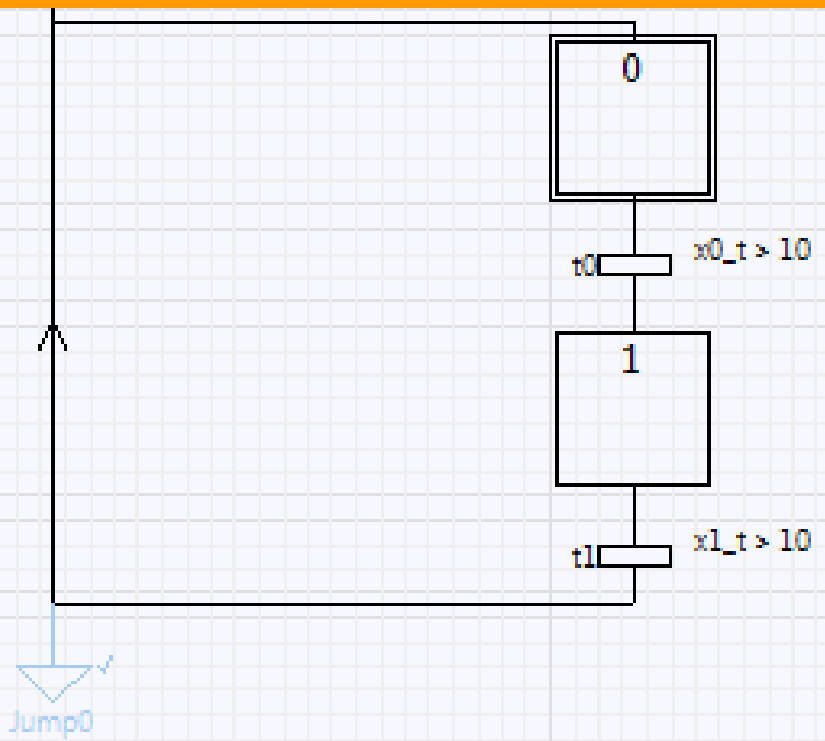


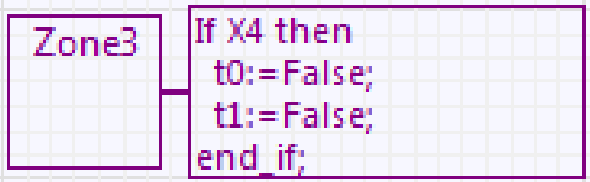
Congelamento

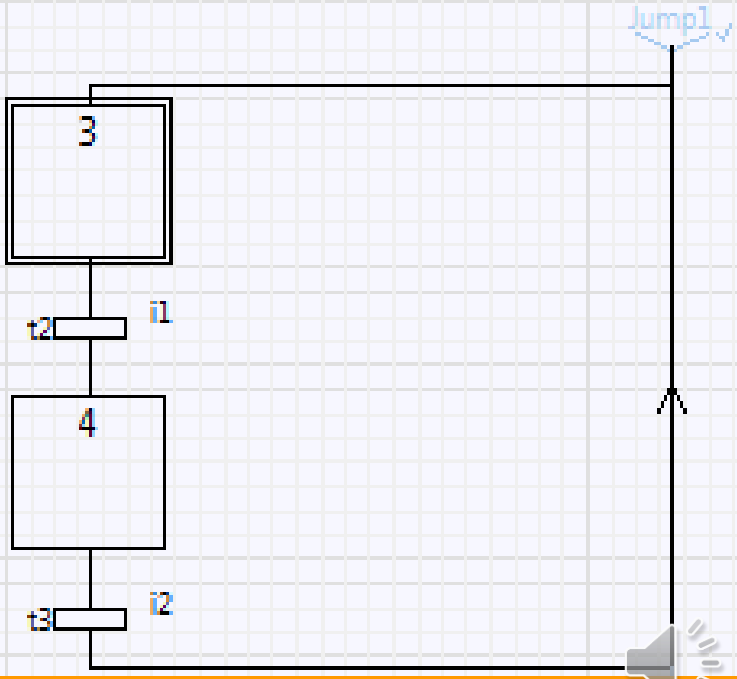


Congelamento

FEUPAutom < versão 5.50





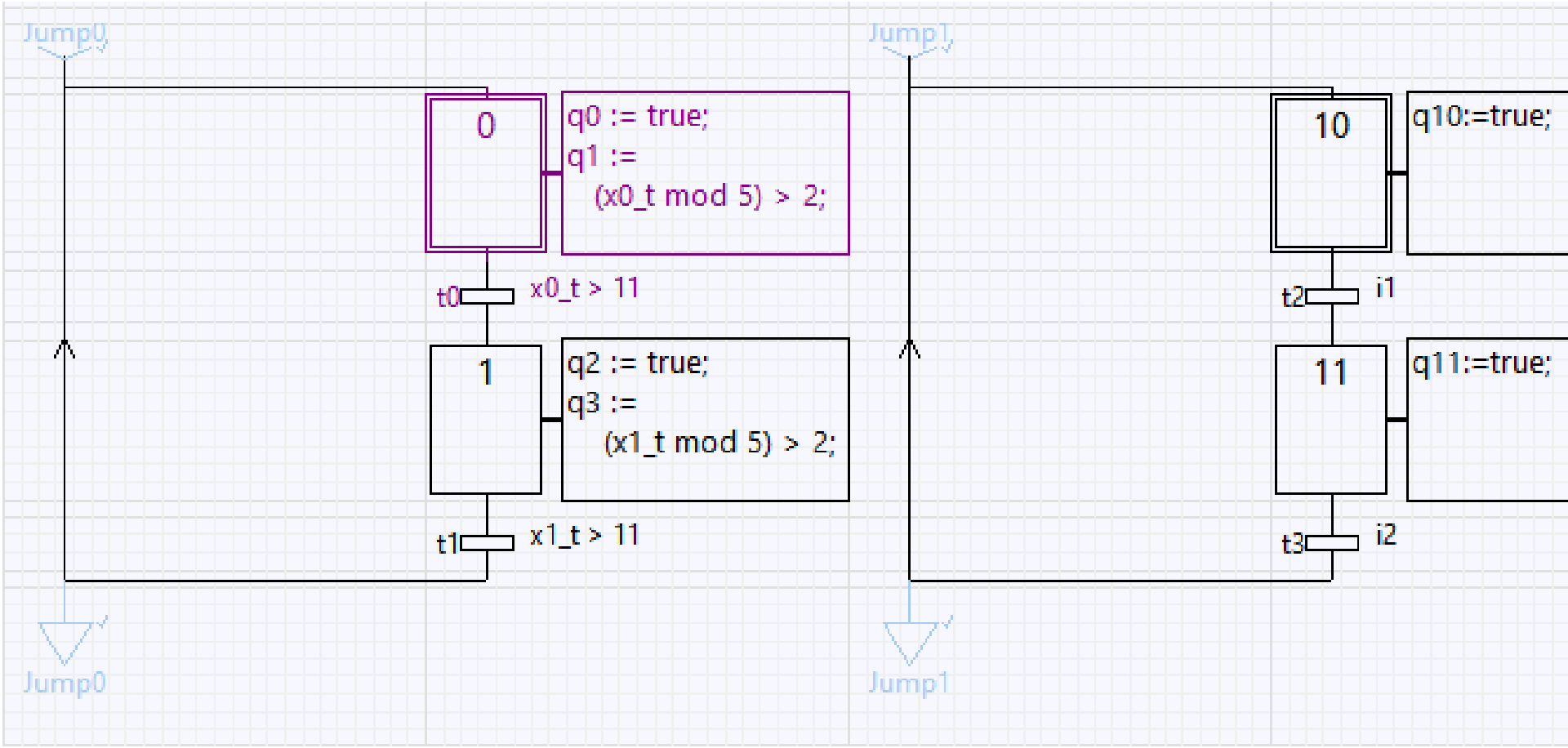


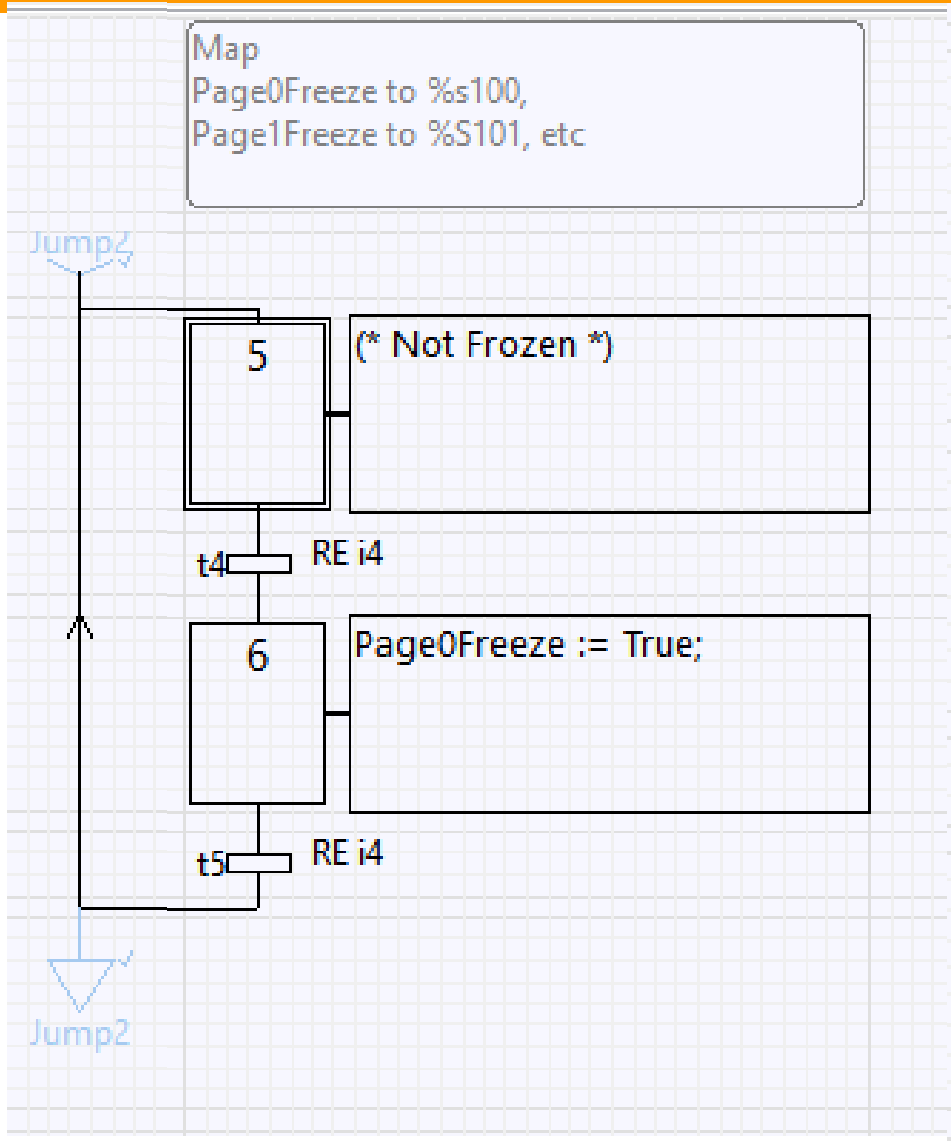
Atenção:
A “Zone3” tem de estar na página das transições a alterar

Freeze, PageStart/Page Clear

FEUPAutom v.5.50+

Página 0





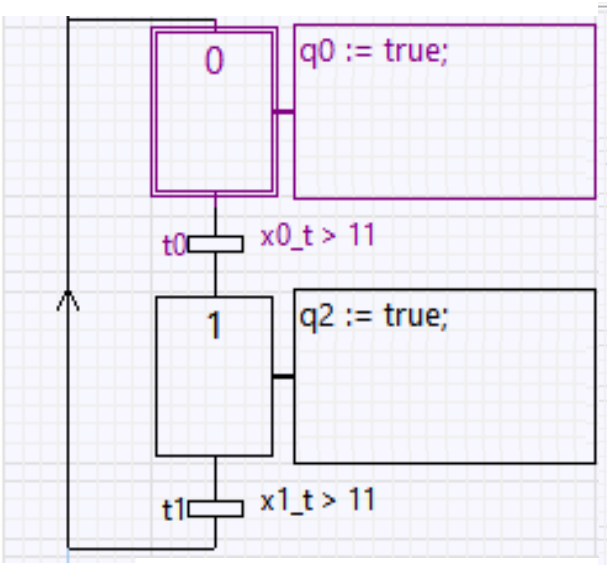

```
100
if RE i6 then
  PageStart(0);
  (*Set Ini Steps + allow evol.*)
end_if;
```

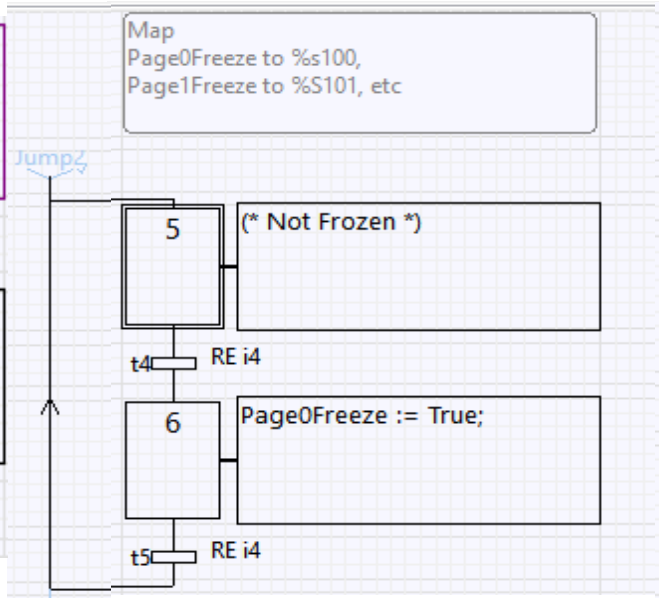
```
101
if i7 then
  PageClear(0);
end_if;
```

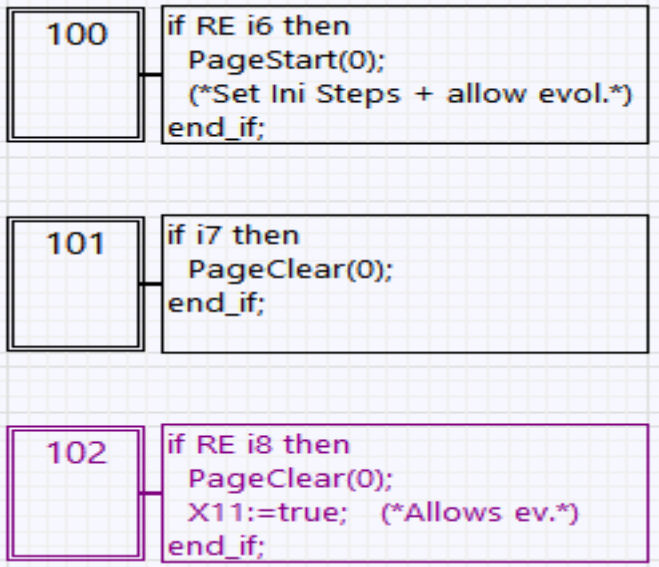
```
102
if RE i8 then
  PageClear(0);
  X11:=true;   (*Allows ev.*)
end_if;
```

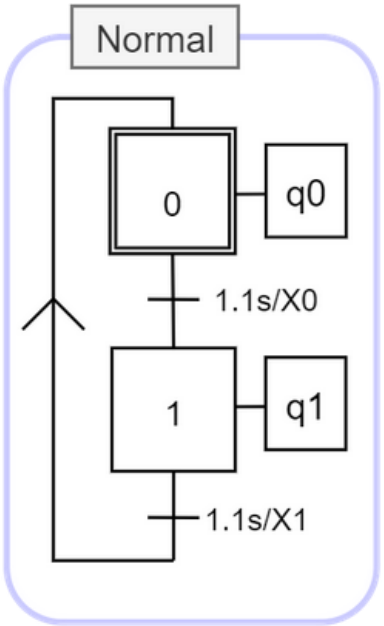
Freeze, PageStart/Page Clear

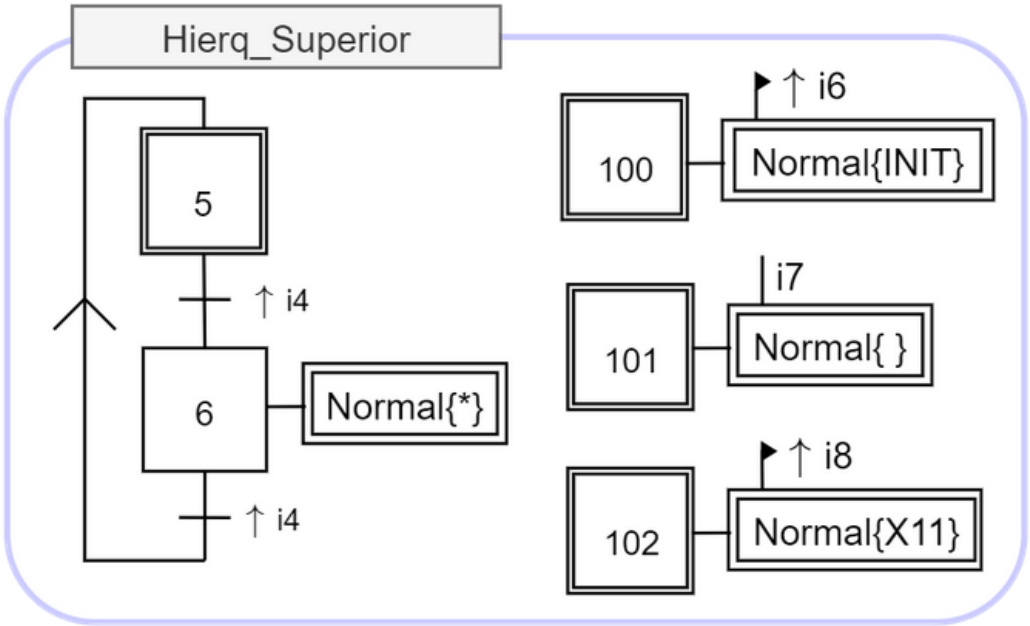
FEUPAutom v.5.50+











FEUPAutom

- ☹ Geração de código “OneWay”
  - ☹ Alterar código do lado gráfico
  - ☹ As erros têm de ser consultados na janela de ST;
  - ☹ Compilar Grafcet faz desaparecer alterações ao ST)

- ☹ Não tem Grafcet hierárquico puro (não tem macro ações)
- ☹ Não tem bits de sistema macro (tal como o Gr7 do PL7)
- ☹ Não tem timers universais do Grafcet (nem TOff)
- ☹ Não tem ações memorizadas
- ☹ Não tem ações impulsionais

FEUPAutom

☺ Estilo próximo da Norma do Grafcet

☺ Tem Páginas de Grafcet (hierarquia limitada)
(permite por exemplo des+ligar etapas)

☺ Tem Hooks (permite por exemplo congelar o Grafcet)

☺ Tem um tempo (décimos segundo) por etapa

☺ Pode gerar código C (entrada ainda em ST)

☺ Há SystemBit para Congelar por página (%s100, %s101, etc)

☺ Há função para arrancar por página (PageStart(…))

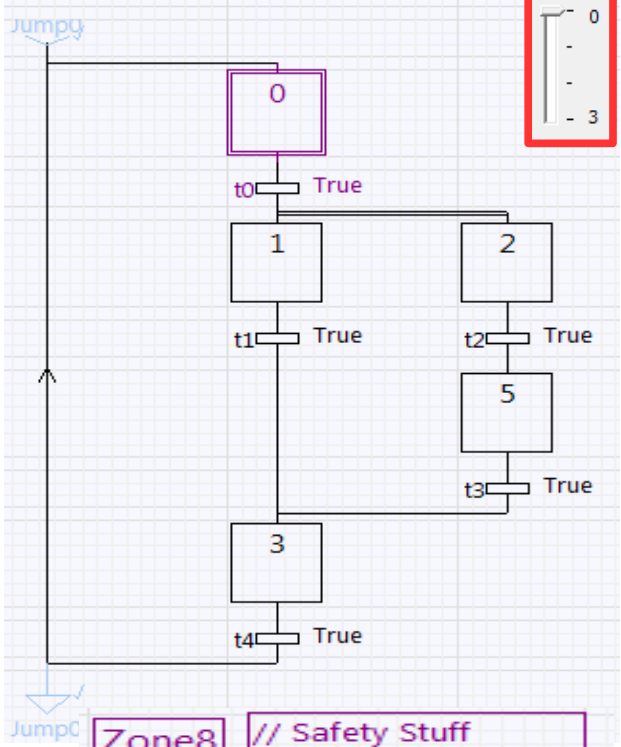
☺ Há função para limpar por página (PageClear(…))

Caso de estudo

Compilar…

Executar…

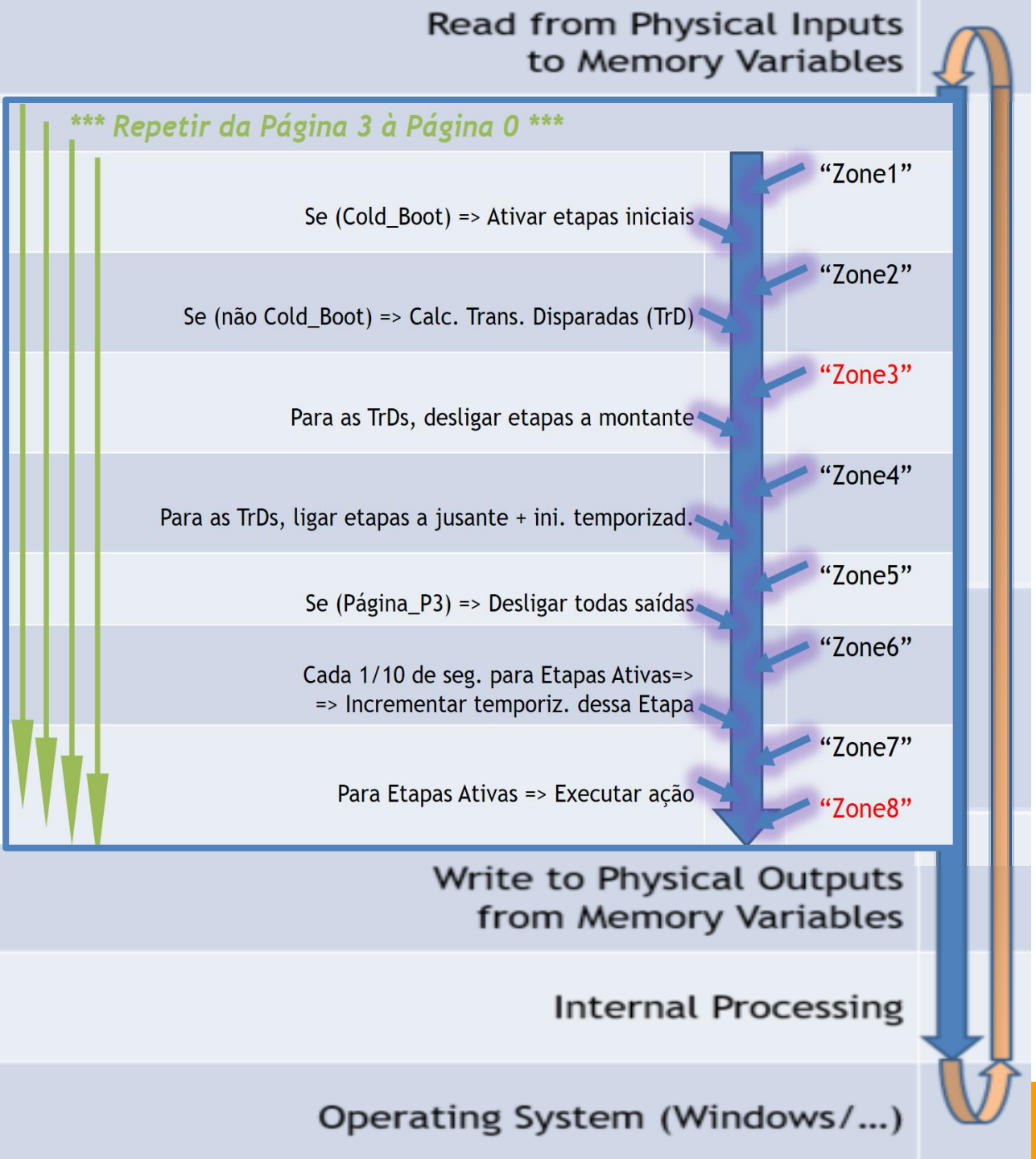
%Name	UserName	%Name	UserName
%M0	X0	%MW0	X0_t
%M1	t0	%MW1	MW1
%M2	X1	%MW2	X1_t
%M3	t1	%MW3	MW3
%M4	M4	%MW4	MW4
%M5	M5	%MW5	MW5
%M6	Zone3	%MW6	Zone3_t
%M7	X9	%MW7	X9_t
%M8	t2	%MW8	MW8
%M9	X4	%MW9	X4_t
%M10	t3	%MW10	MW10
%M11	M11	%MW11	MW11
%M12	M12	%MW12	MW12
%M13	X5	%MW13	X5_t
%M14	t4	%MW14	MW14
%M15	X6	%MW15	X6_t
%M16	t5	%MW16	MW16
%M17	M17	%MW17	MW17
%M18	M18	%MW18	MW18
%M19	Zone8	%MW19	Zone8_t
%M20	t6	%MW20	MW20
%M21	X99	%MW21	X99_t
%M22	M22	%MW22	MW22
%M23	M23	%MW23	MW23
%M24	M24	%MW24	MW24
%M25	M25	%MW25	MW25




```
Zone8
// Safety Stuff
if q0 and q1 then
  q0:=false;
end_if;
```

```
Zone3
If X4 then
  t0:=False;
  t1:=False;
  t2:=False;
  t3:=False;
  t4:=False;
end_if;
```

```
99
// Do Stuff
q0:=i0;
```


Read from Physical Inputs
to Memory Variables
*** Repetir da Página 3 à Página 0 ***
"Zone1"
Se (Cold_Boot) => Ativar etapas iniciais
"Zone2"
Se (não Cold_Boot) => Calc. Trans. Disparadas (TrD)
"Zone3"
Para as TrDs, desligar etapas a montante
"Zone4"
Para as TrDs, ligar etapas a jusante + ini. temporizad.
"Zone5"
Se (Página_P3) => Desligar todas saídas
"Zone6"
Cada 1/10 de seg. para Etapas Ativas=>
=> Incrementar temporiz. dessa Etapa
"Zone7"
Para Etapas Ativas => Executar ação
"Zone8"
Write to Physical Outputs
from Memory Variables
Internal Processing
Operating System (Windows/...)

Read from Physical Inputs
to Memory Variables

*** Repetir da Página 3 à Página 0 ***

"Zone1"

Se (Cold_Boot) => Ativar etapas iniciais

"Zone2"

Se (não Cold_Boot) => Calc. Trans. Disparadas (TrD)

"Zone3"

Para as TrDs, desligar etapas a montante

"Zone4"

Para as TrDs, ligar etapas a jusante + ini. temporizad.

"Zone5"

Se (Página_P3) => Desligar todas saídas

"Zone6"

Cada 1/10 de seg. para Etapas Ativas=>
=> Incrementar temporiz. dessa Etapa

"Zone7"

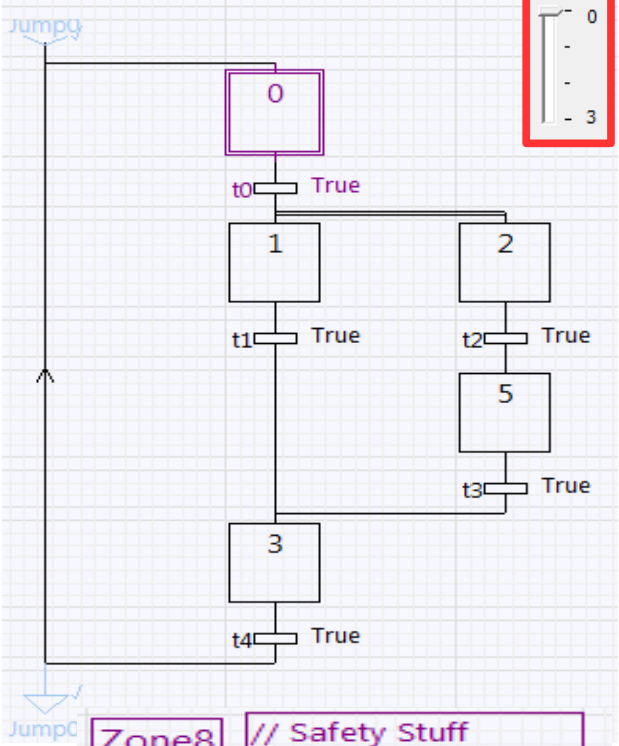
Para Etapas Ativas => Executar ação

"Zone8"

Write to Physical Outputs
from Memory Variables

Internal Processing

Operating System (Windows/...)

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if q0 and q1 then
  q0:=false;
end_if;
```

```
Zone3
If X4 then
  t0:=False;
  t1:=False;
  t2:=False;
  t3:=False;
  t4:=False;
end_if;
```

```
99
// Do Stuff
q0:=i0;
```

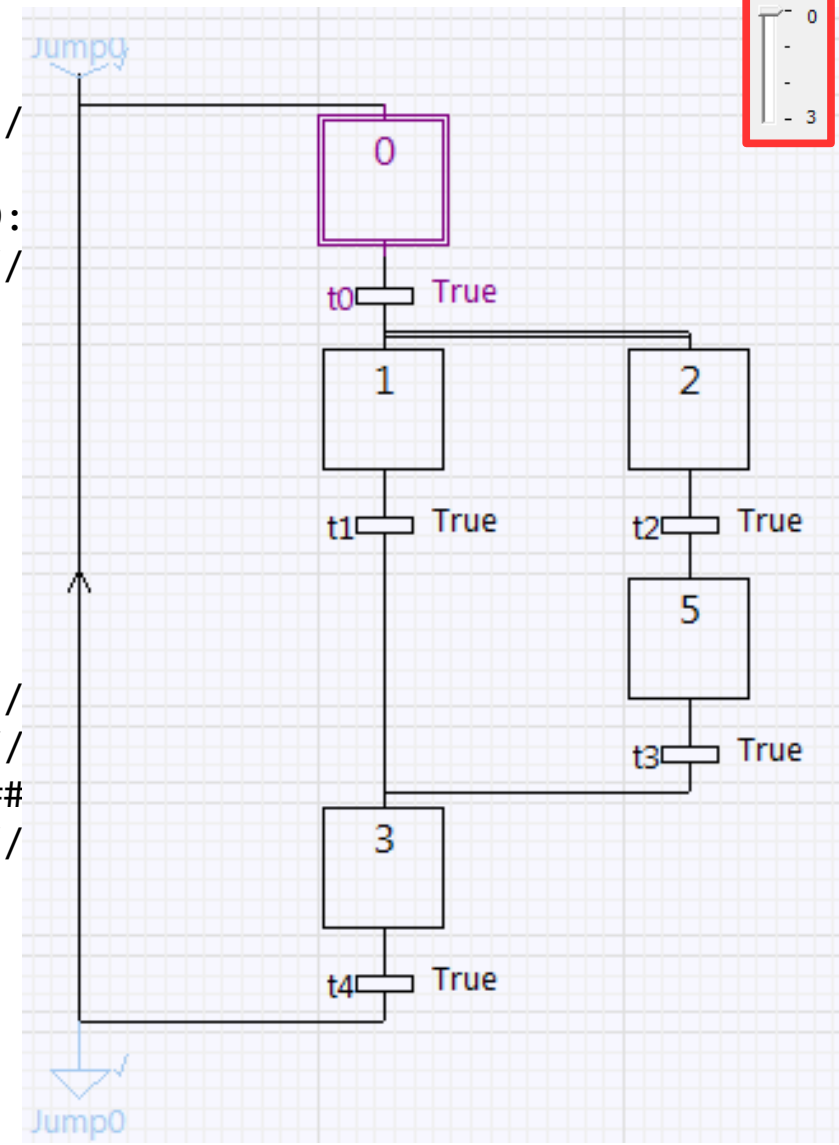
```
////////////////////////////////////////////////
// FEUPAutom - 5.9.0.98 -
// Code Automatically Generated:2019-04-04 16:09:
////////////////////////////////////////////////



//########################################//
//################ Page 3 ##############//
//########################################//

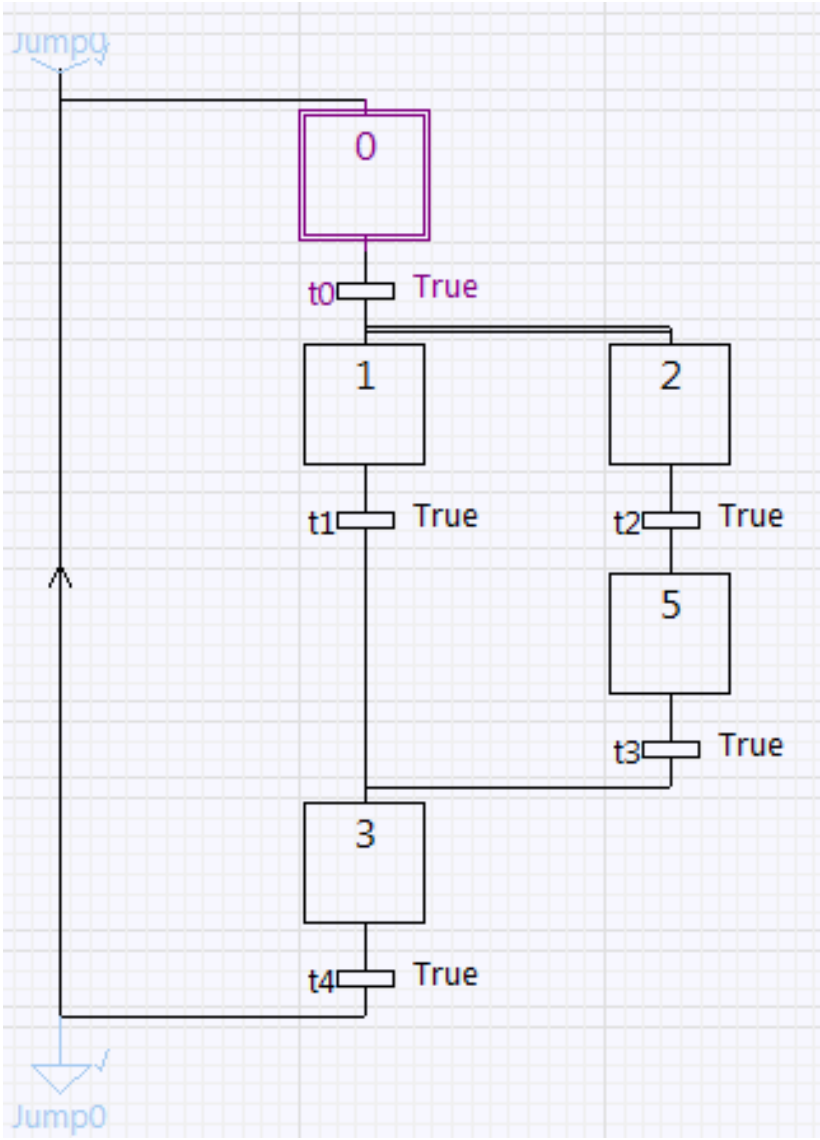
////////////////////////////////////////////////
////////////// If boot => Set Initial Steps //////
//######################## Page 3 ################
////////////////////////////////////////////////

  If (sw0=0) Then
  End_If;
```



```
Q0:=False;
Q1:=False;
Q2:=False;
Q3:=False;
Q4:=False;
...
```

```
%s100 := False;
%s101 := False;
%s102 := False;
```

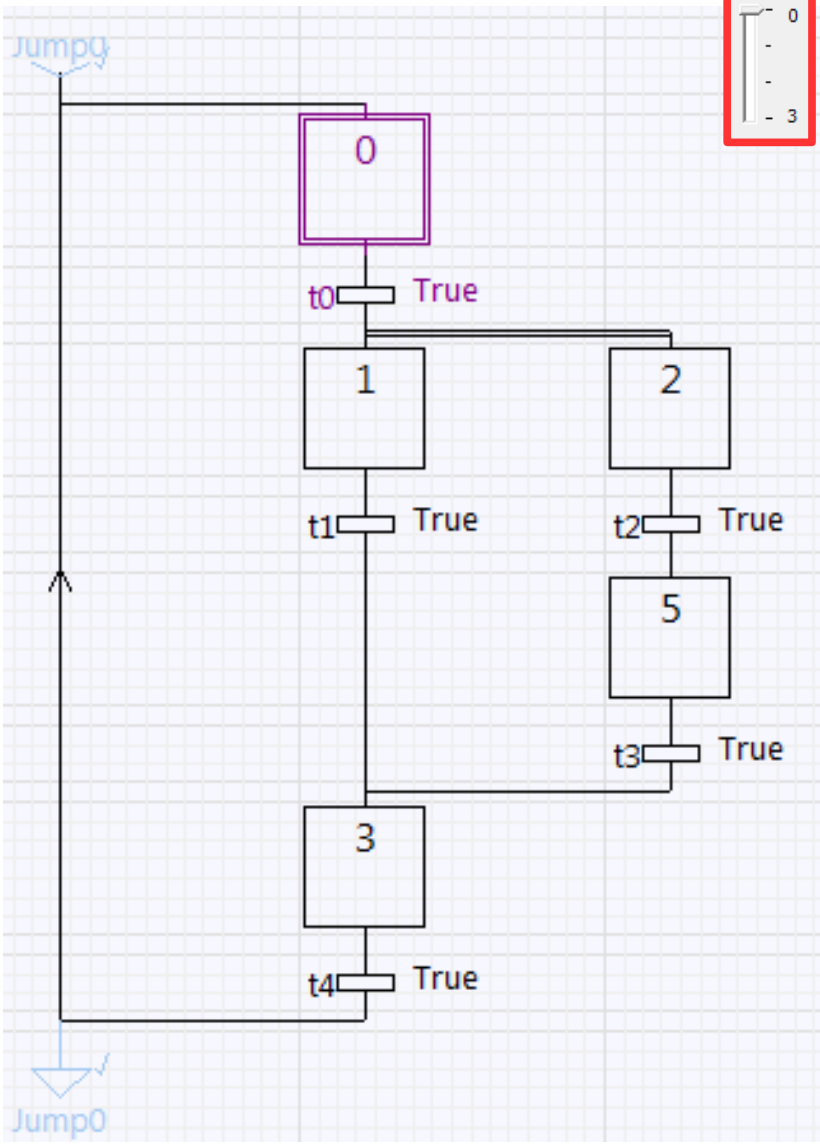


```
//########################################//
//################ Page 2 ###############//
//########################################//

...
```

```
//########################################//
//################ Page 1 ###############//
//########################################//

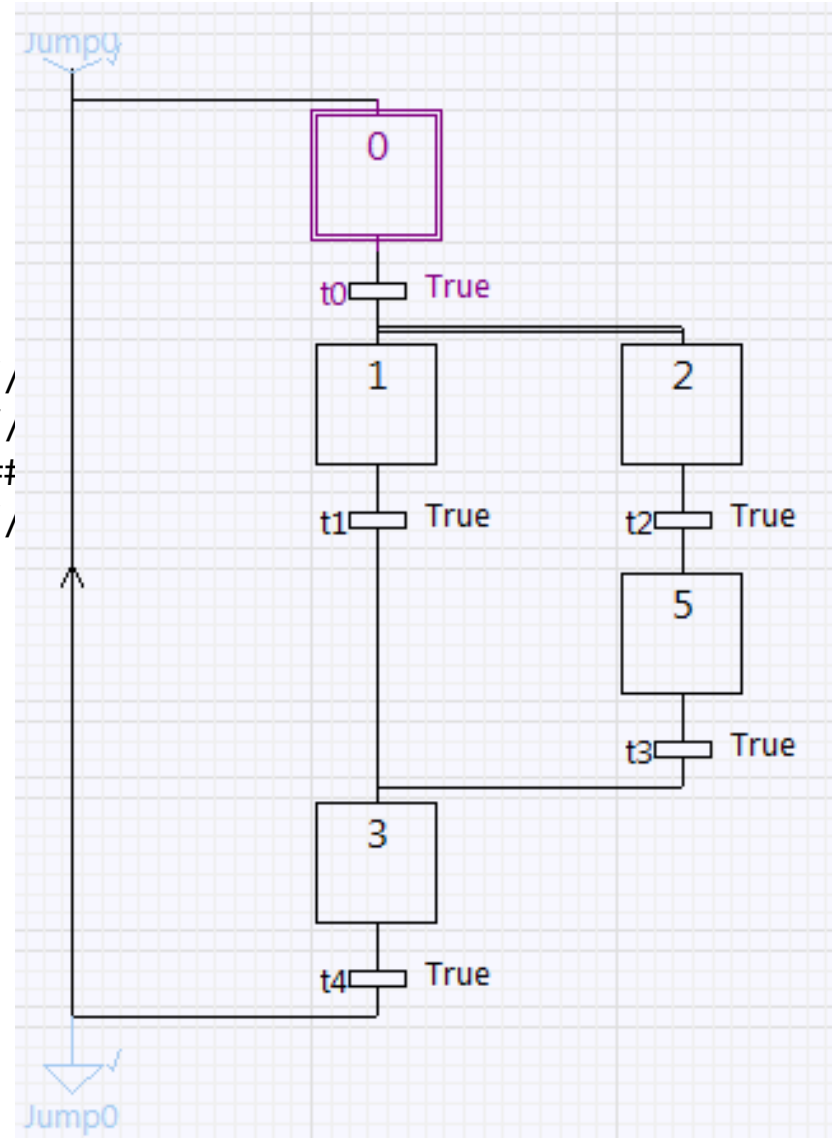
...
```



```
//########################################//
//################ Page 0 ################//
//########################################//


////////////////////////////////////////////////
//////// If boot => Set Initial Steps ////////
//#################### Page 0 ##################
////////////////////////////////////////////////

  If (sw0=0) Then
    // ObjIdx=0 => INI_Step "X0"
    X0 := True;
  End_If;
```



Obs:

Id=ObjIdx=0 =>

%M0 é X0 e %MW0 é X0_t

```
////////////////////////////////////////////////
///////////////// Calc Fired Transitions ///////
//####################### Page 0 ###############
////////////////////////////////////////////////

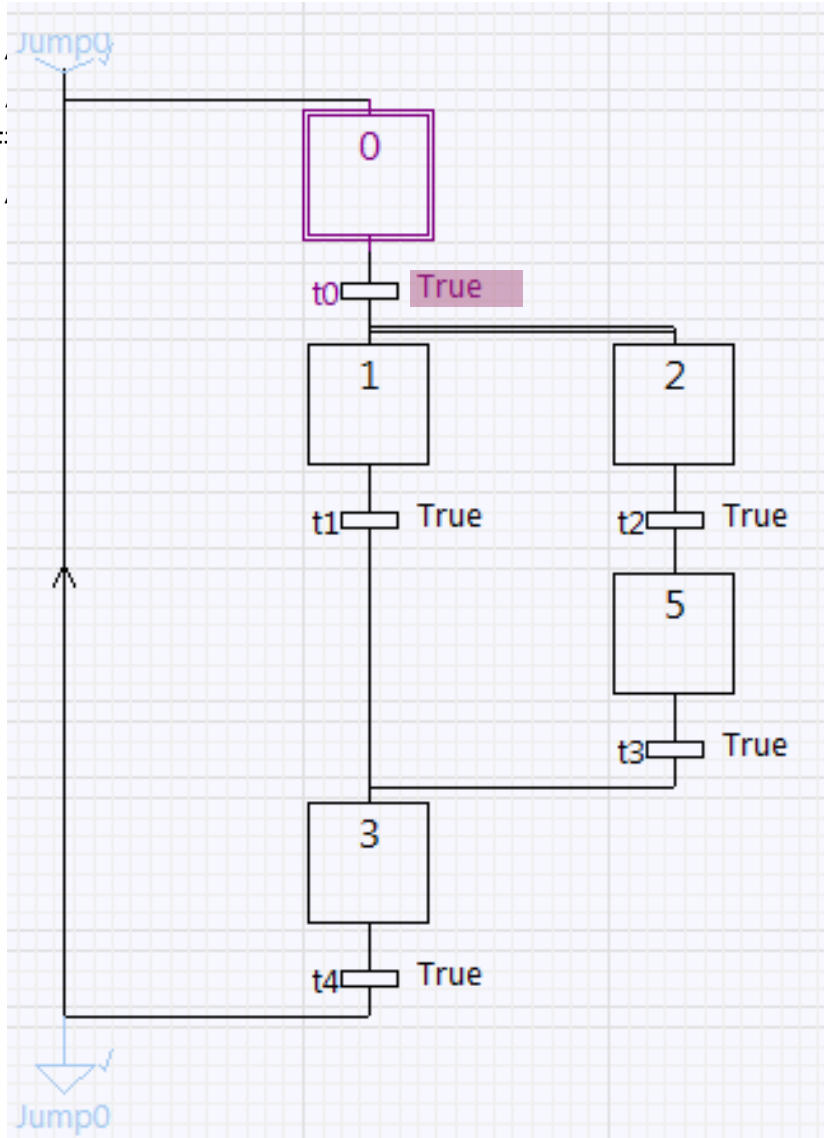
// ObjIdx=1 => Transition "t0"
  // Steps Above: id=0 => X0 ;
  t0 :=  X0 AND  (True);

// ObjIdx=4 => Transition "t1"
  // Steps Above: id=2 => X1 ;
  t1 :=  X1 AND  (True);

// ObjIdx=5 => Transition "t2"
  // Steps Above: id=3 => X2 ;
  t2 :=  X2 AND  (True);

// ObjIdx=7 => Transition "t3"
  // Steps Above: id=6 => X5 ;
  t3 :=  X5 AND  (True);

// ObjIdx=9 => Transition "t4"
  // Steps Above: id=8 => X3 ;
  t4 :=  X3 AND  (True);
```



```
////////////////////////////////////////////////
///////////////// Calc Fired Transitions ///////
//####################### Page 0 ###############
////////////////////////////////////////////////
```

// FEUPAutom v.5.50+

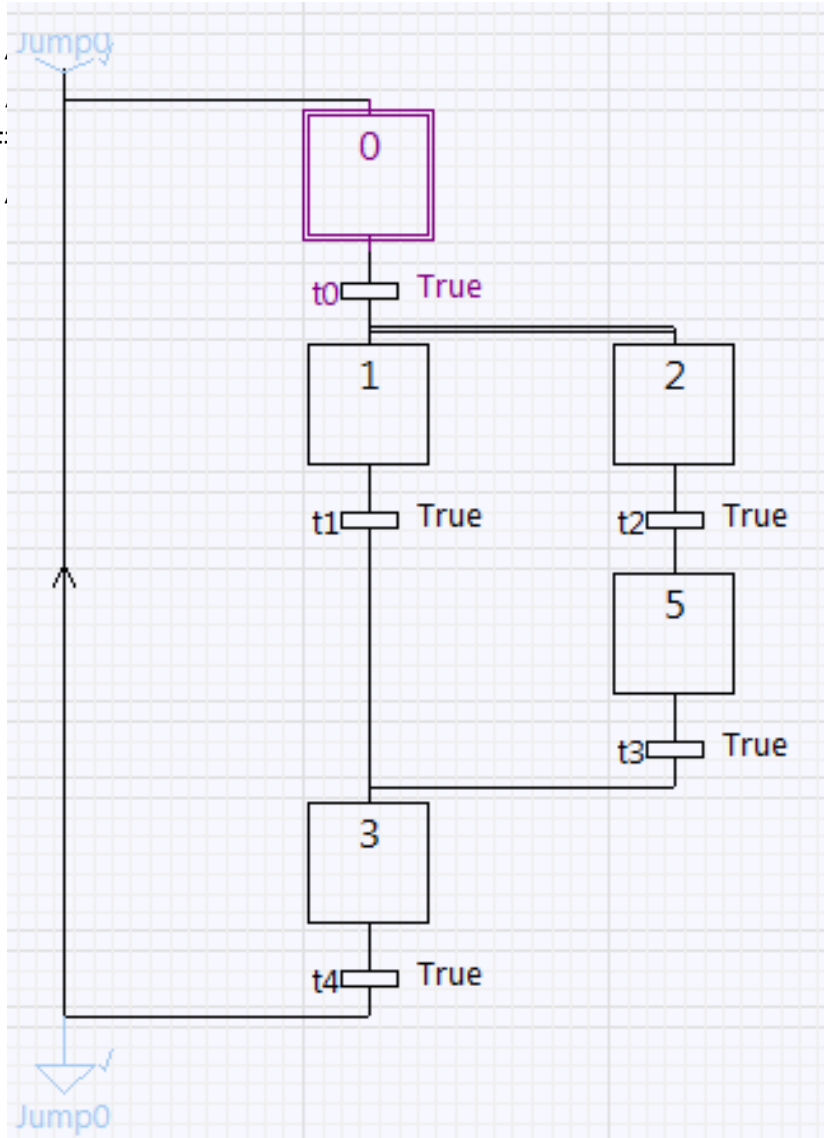
```
// ObjIdx=1 => Transition "t0"
  // Steps Above: id=0 => X0 ;
  t0 := (NOT %s100) AND ( X0 AND  (True) );

// ObjIdx=4 => Transition "t1"
  // Steps Above: id=2 => X1 ;
  t1 := (NOT %s100) AND ( X1 AND  (True) );

// ObjIdx=5 => Transition "t2"
  // Steps Above: id=3 => X2 ;
  t2 := (NOT %s100) AND ( X2 AND  (True) );

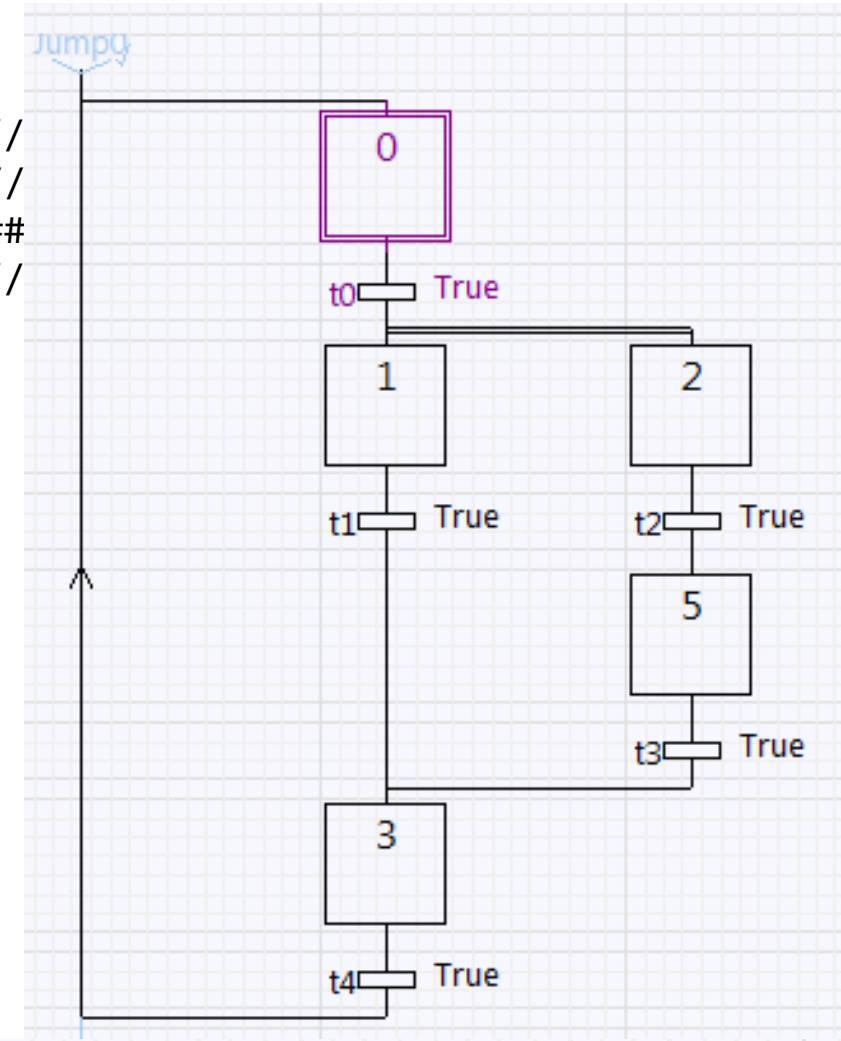
// ObjIdx=7 => Transition "t3"
  // Steps Above: id=6 => X5 ;
  t3 := (NOT %s100) AND ( X5 AND  (True) );

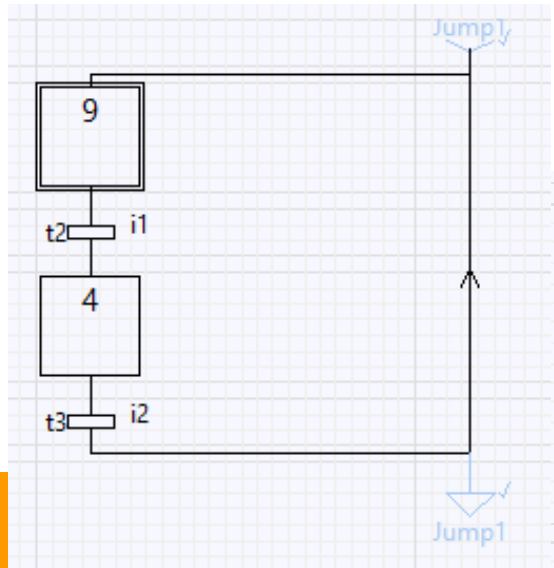
// ObjIdx=9 => Transition "t4"
  // Steps Above: id=8 => X3 ;
  t4 := (NOT %s100) AND ( X3 AND  (True) );
```

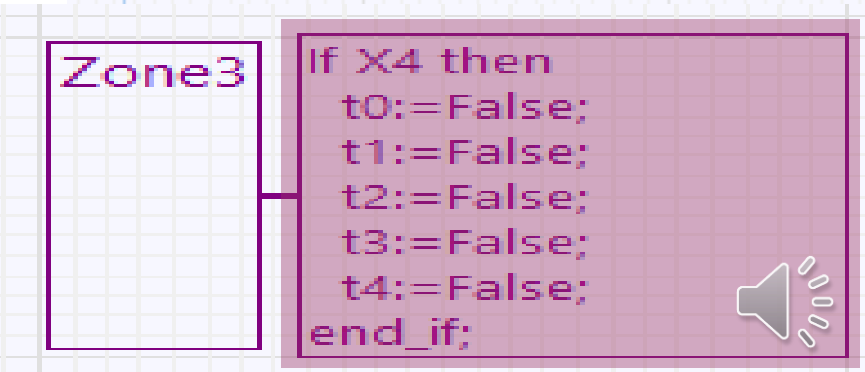


```
////////////////////////////////////////////////
/////////////////////////// Zone3 ///////////////
//######################## Page 0 ###############
////////////////////////////////////////////////
```

```
If X4 then
   t0:=False;
   t1:=False;
   t2:=False;
   t3:=False;
   t4:=False;
 end_if;
```

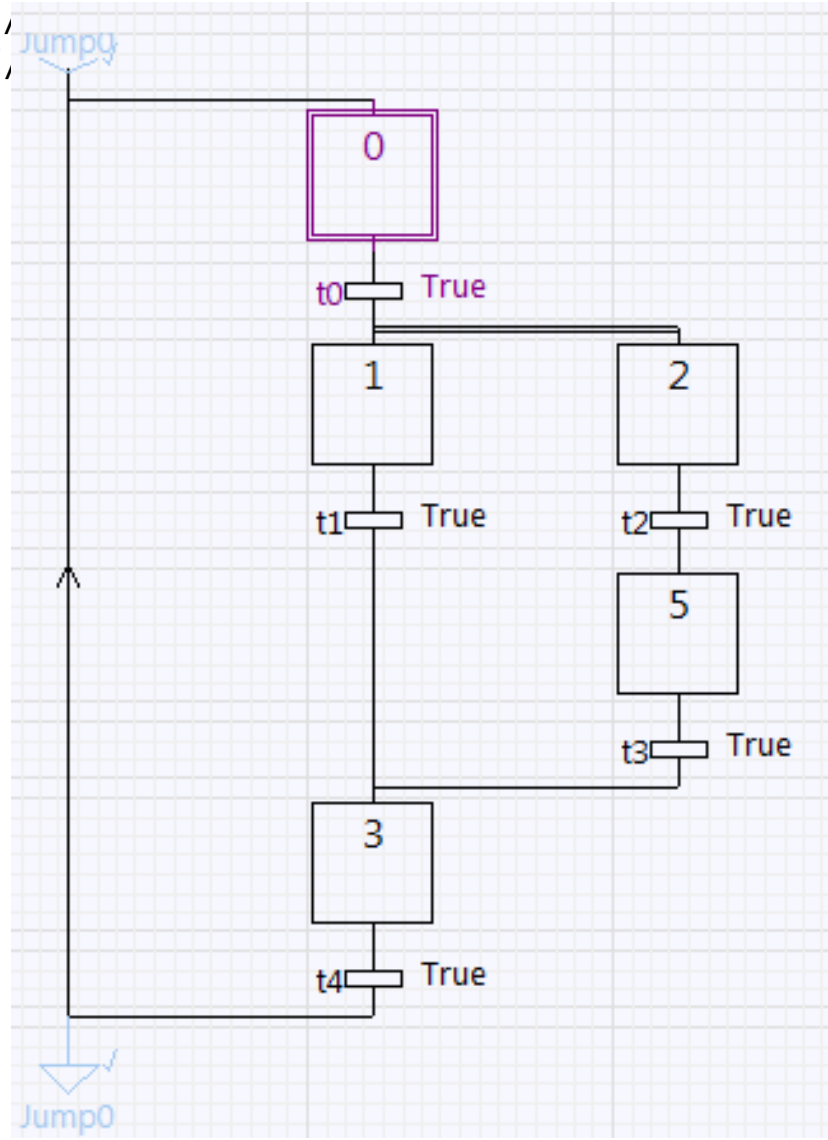






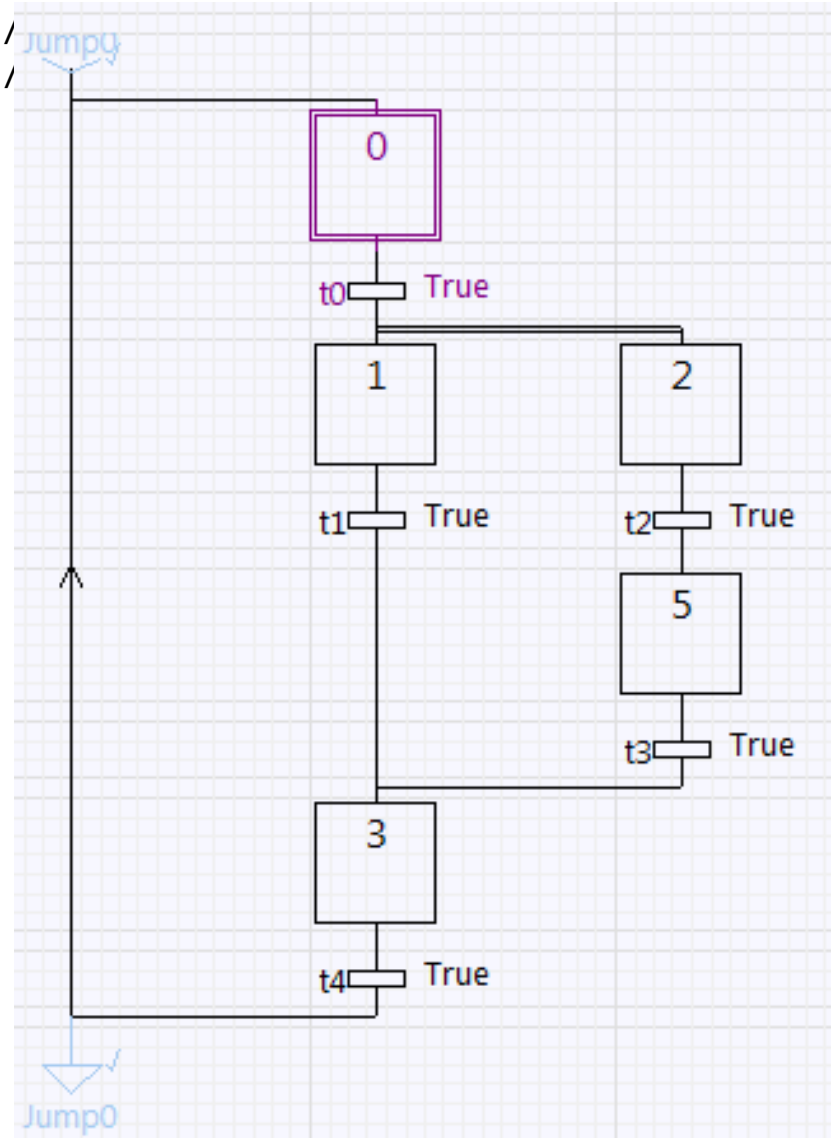
```
////////////////////////////////////////////////////
///////////////// ReSet Steps Above fired Tr //////

// ObjIdx=1 => Transition "t0"
  // Steps Above: id=0 => X0 ;
  If (t0) Then
     X0:=False;
  End_If;
// ObjIdx=4 => Transition "t1"
  // Steps Above: id=2 => X1 ;
  If (t1) Then
     X1:=False;
  End_If;
// ObjIdx=5 => Transition "t2"
  // Steps Above: id=3 => X2 ;
  If (t2) Then
     X2:=False;
  End_If;
// ObjIdx=7 => Transition "t3"
  // Steps Above: id=6 => X5 ;
  If (t3) Then
     X5:=False;
  End_If;
// ObjIdx=9 => Transition "t4"
  // Steps Above: id=8 => X3 ;
If (t4) Then
     X3:=False;
  End_If;
```



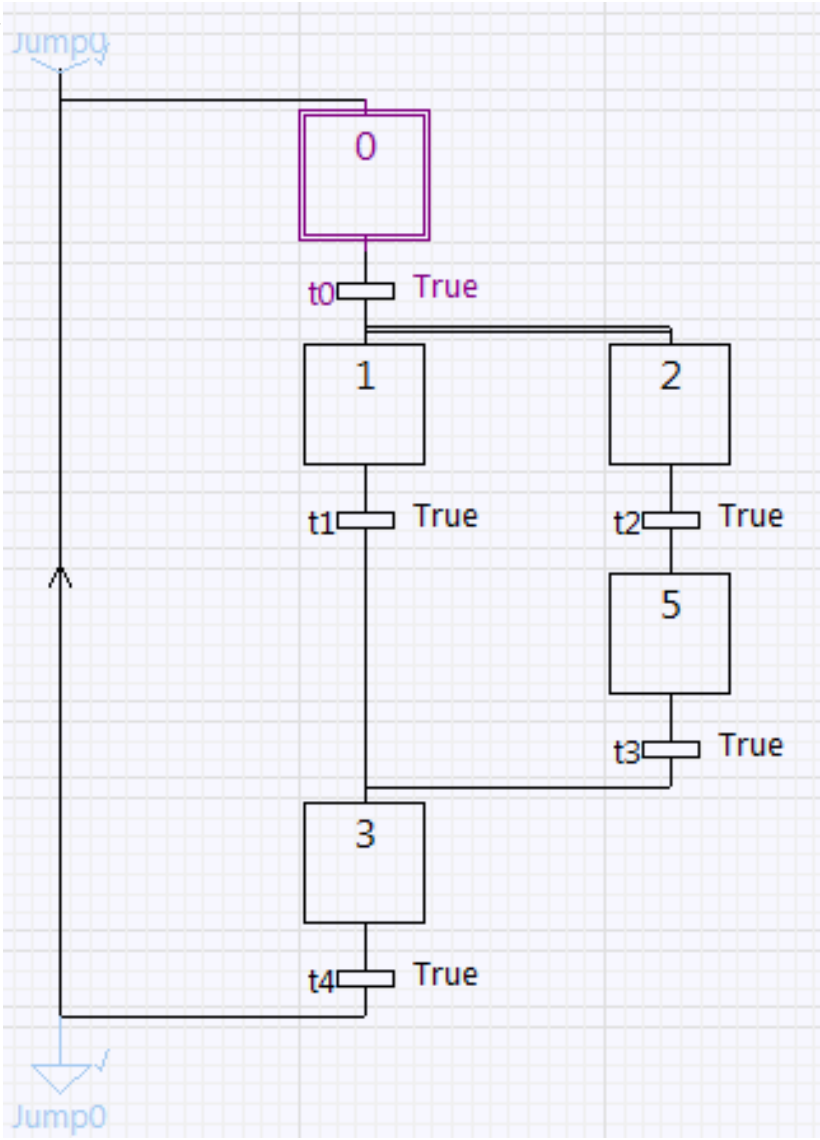
```
////////////////////////////////////////////////////
///////////////// Set Steps below fired Tr /////////

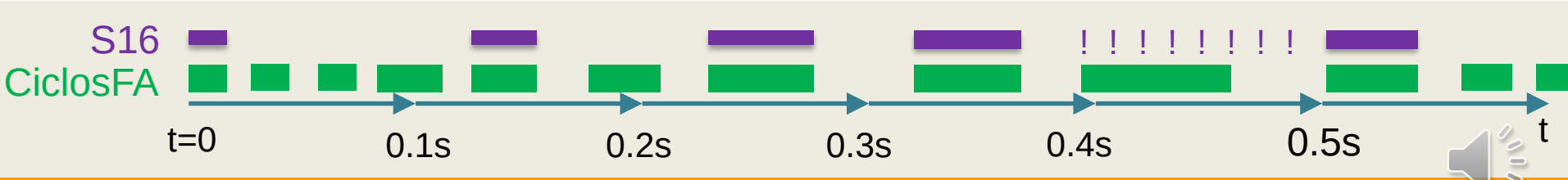
// ObjIdx=1 => Transition "t0"
  // Steps Below: id=2 => X1 ;id=3 => X2 ;
  If (t0) Then
    X1 := True;  X2 := True;
    X1_T := 0; X2_T := 0;
  End_If;
// ObjIdx=4 => Transition "t1"
  // Steps Below: id=8 => X3 ;
  If (t1) Then
    X3 := True;     X3_T := 0;
  End_If;
// ObjIdx=5 => Transition "t2"
  // Steps Below: id=6 => X5 ;
  If (t2) Then
    X5 := True;     X5_T := 0;
  End_If;
// ObjIdx=7 => Transition "t3"
  // Steps Below: id=8 => X3 ;
  If (t3) Then
    X3 := True;     X3_T := 0;
  End_If;
// ObjIdx=9 => Transition "t4"
  // Steps Below: id=0 => X0 ;
  If (t4) Then
    X0 := True;     X0_T := 0;
End_If;
```



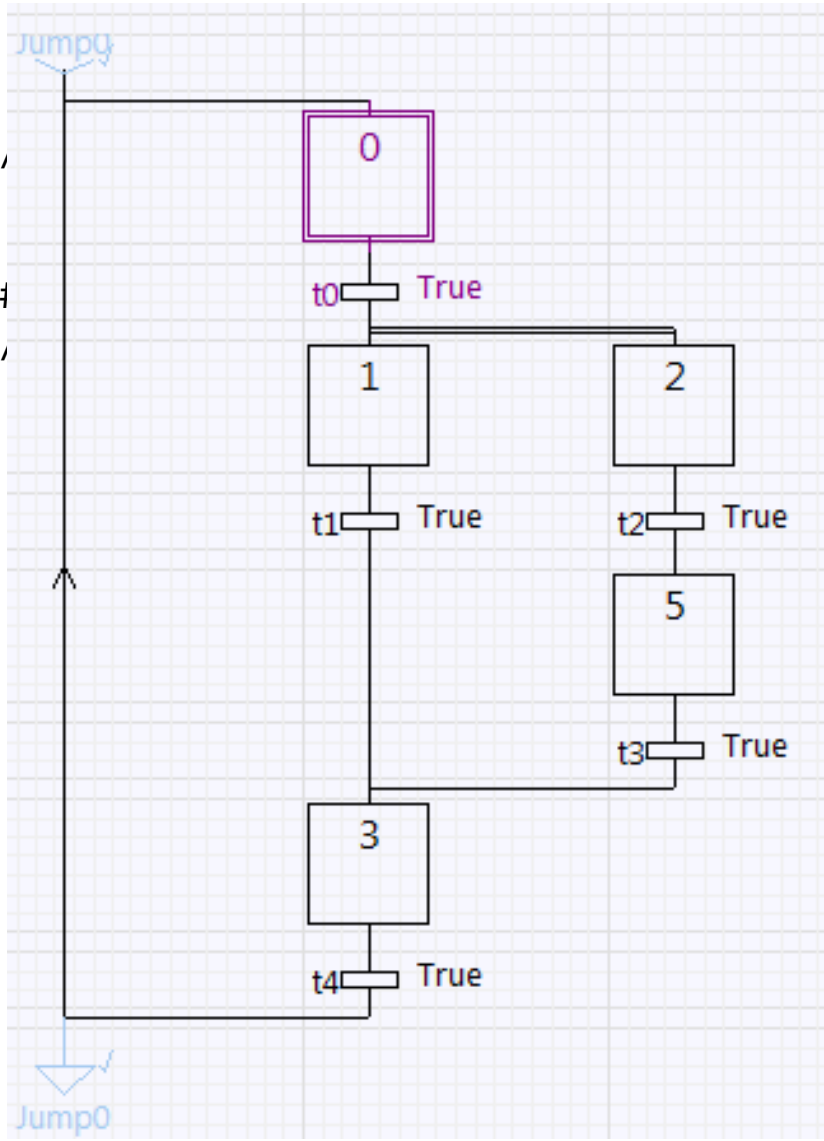
```
////////////////////////////////////////////////
///// If step active increment MW timer of step

  // ObjIdx=0 => Step "X0"
  If (s16) and (X0) Then
    X0_T := X0_T+1;
  end_if;
  // ObjIdx=2 => Step "X1"
  If (s16) and (X1) Then
    X1_T := X1_T+1;
  end_if;
  // ObjIdx=3 => Step "X2"
  If (s16) and (X2) Then
    X2_T := X2_T+1;
  end_if;
  // ObjIdx=6 => Step "X5"
  If (s16) and (X5) Then
    X5_T := X5_T+1;
  end_if;
  // ObjIdx=8 => Step "X3"
  If (s16) and (X3) Then
    X3_T := X3_T+1;
  end_if;
```



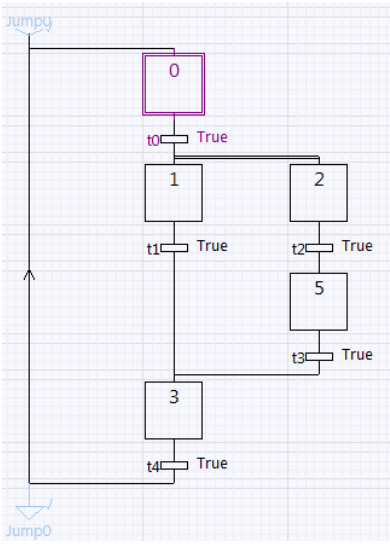


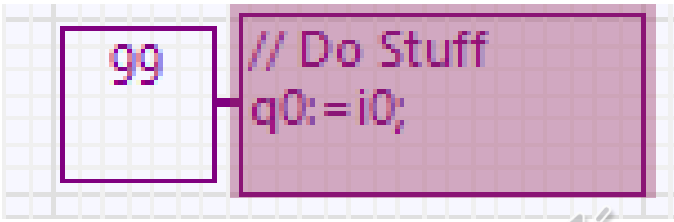
```
////////////////////////////////////////////////
//////// If step active,
//////// execute its action code
//######################## Page 0 ################
////////////////////////////////////////////////
```



```
////////////////////////////////////////////////////////////
//////// If step active, execute its action code ///////////
//######################## Page 0 ########################//
////////////////////////////////////////////////////////////

  // ObjIdx=21 => Step "X99" (code...)
  If X99 Then
    // Do Stuff
    q0:=i0;
  End_If;
```

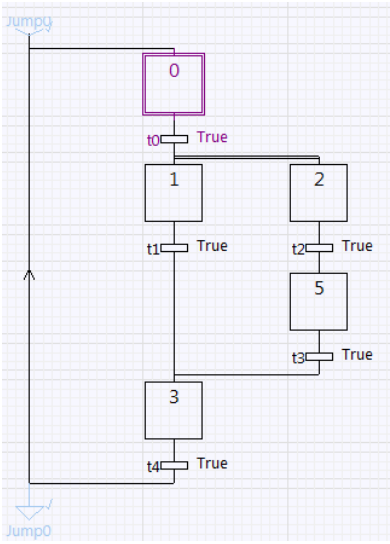


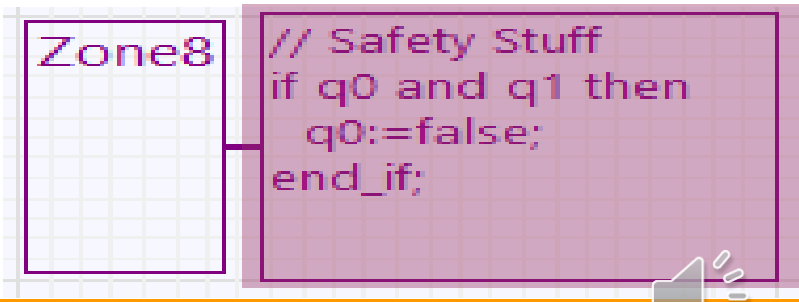


```
////////////////////////////////////////////////////////////
/////////////////////////// Zone8 ///////////////////////////
//######################### Page 0 ########################//
////////////////////////////////////////////////////////////
```

```
// Safety Stuff
if q0 and q1 then
   q0:=false;
end_if;
```

```
(*************** End of ST Code ***************)
```



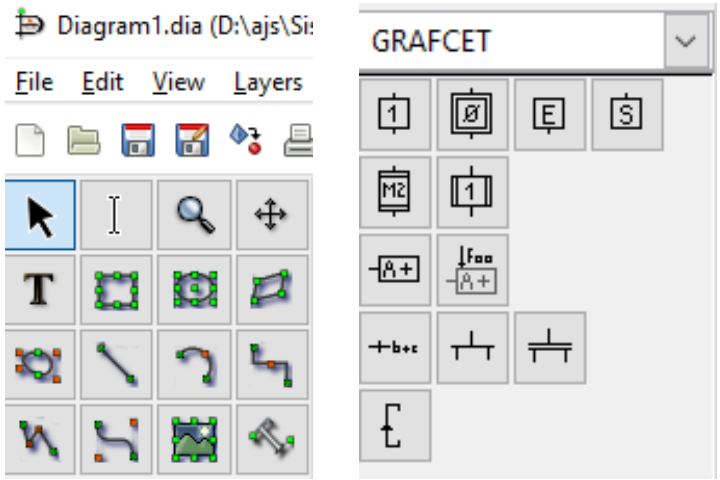


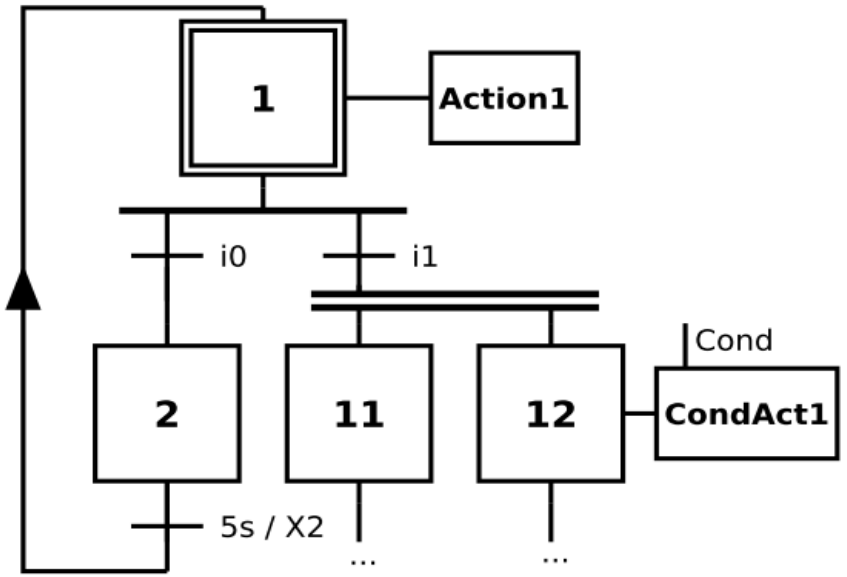
Comparação

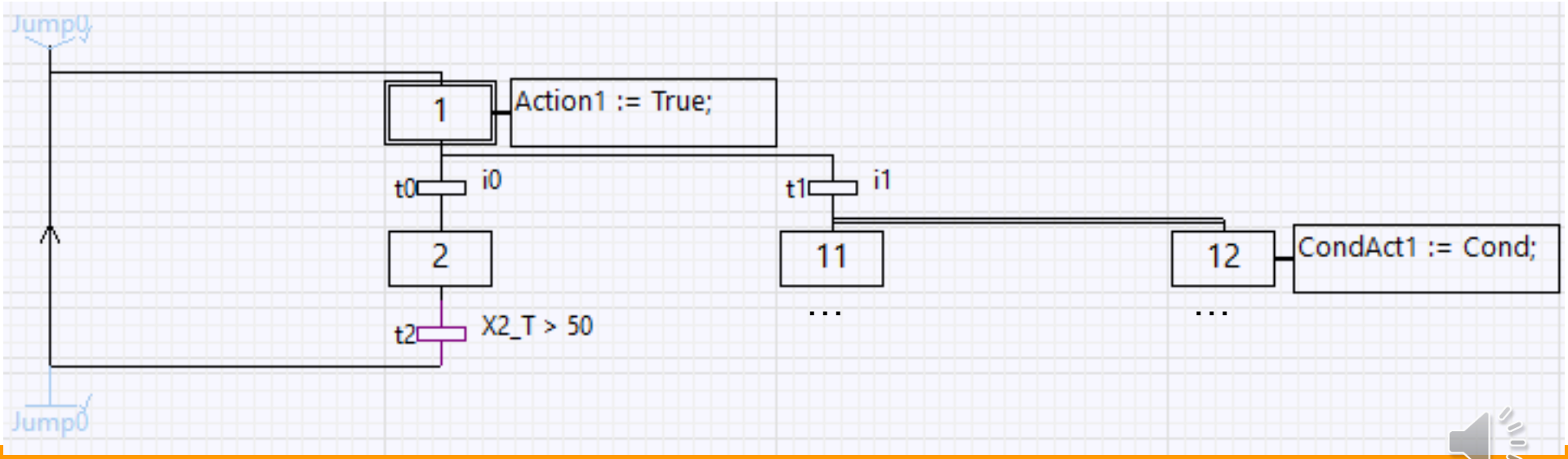
Norma

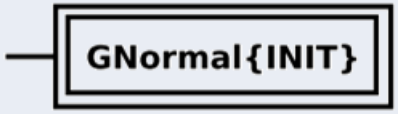
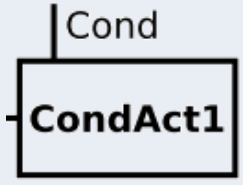
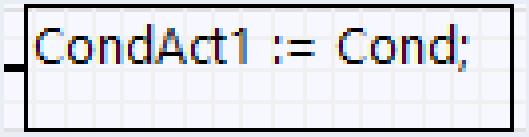
FEUPautom

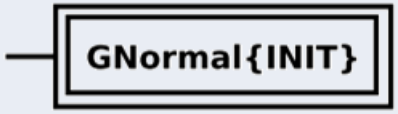
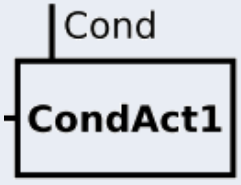
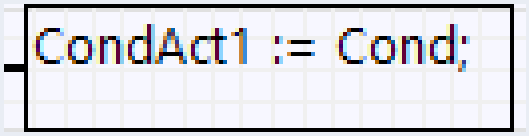
Norma 848 vs FEUPAutomGrafcet





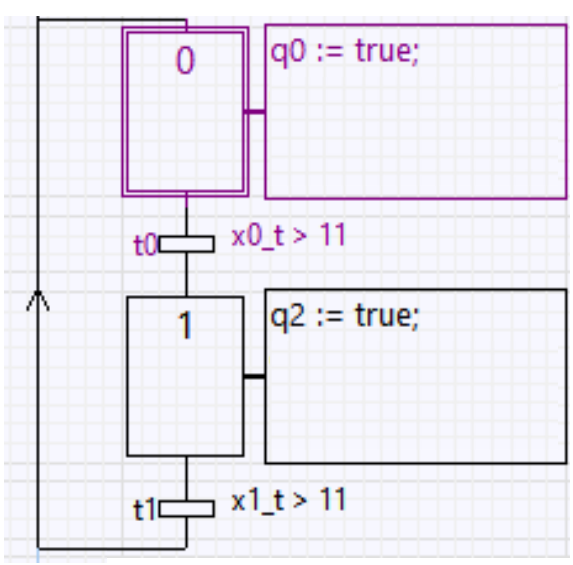


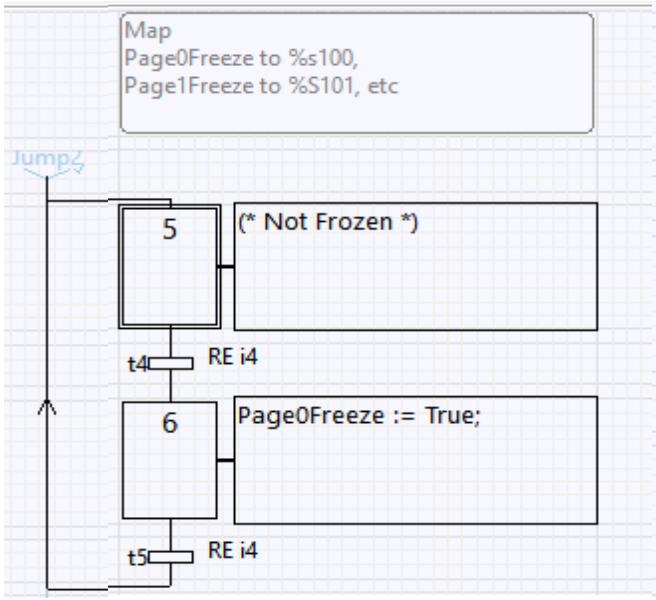
Norma Grafcet 848	Grafcet FEUPAutom *<5.50*
2 s / X5	X5_T > 20
	Manually reset all implicated steps (in a page with higher number / rank) $X_{all\_implicated}$:= false; ...
	Manually set and reset all steps involved (in a page with higher number / rank) X_{listed_steps} := true; ... X_{all_others} := false; ...
	Manually set and reset all steps involved (in a page with higher number / rank) $X_{initial\_steps}$:= true; ... X_{all_others} := false; ...
	Use code in the “Zone3” special step to manually reset transitions implicated in the freeze macro action $T_{all\_implicated}$:= false; ...
	

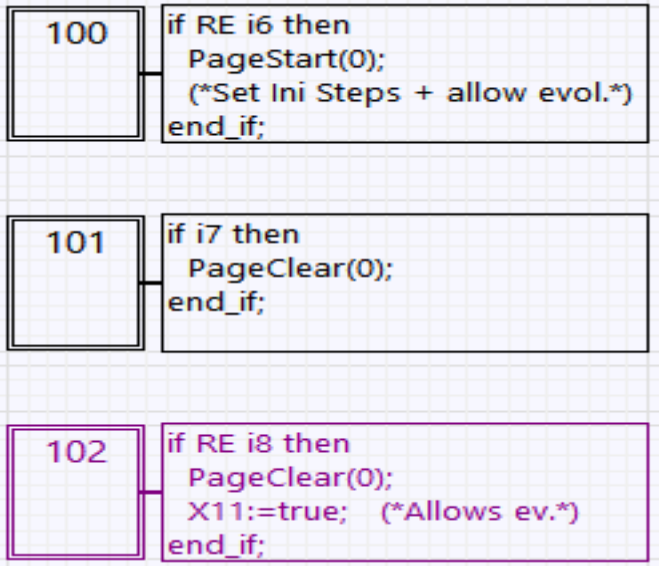
Norma Grafcet 848	Grafcet FEUPAutom *v5.50+*
2 s / X5	X5_T > 20
	In a page with higher number / rank **`PageClear(PageNumber)`**
	In a page with higher number / rank **`PageClear(PageNumber)`** and then set steps X_{listed_steps} **`:= true; ...`**
	In a page with higher number / rank **`PageStart(PageNumber)`**
	In a page with higher number / rank, use system bit Page0Freeze➔%s100, Page1Freeze➔%s101, etc
	

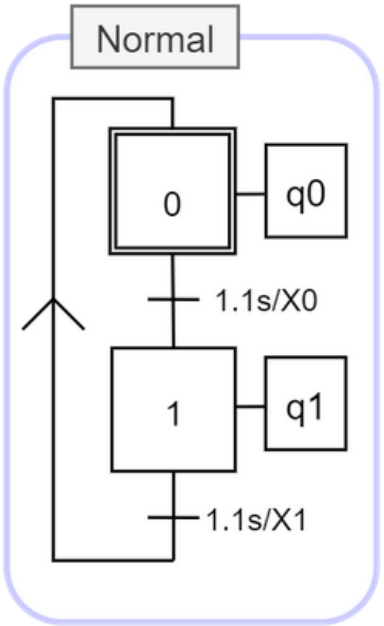
Freeze, PageStart/Page Clear

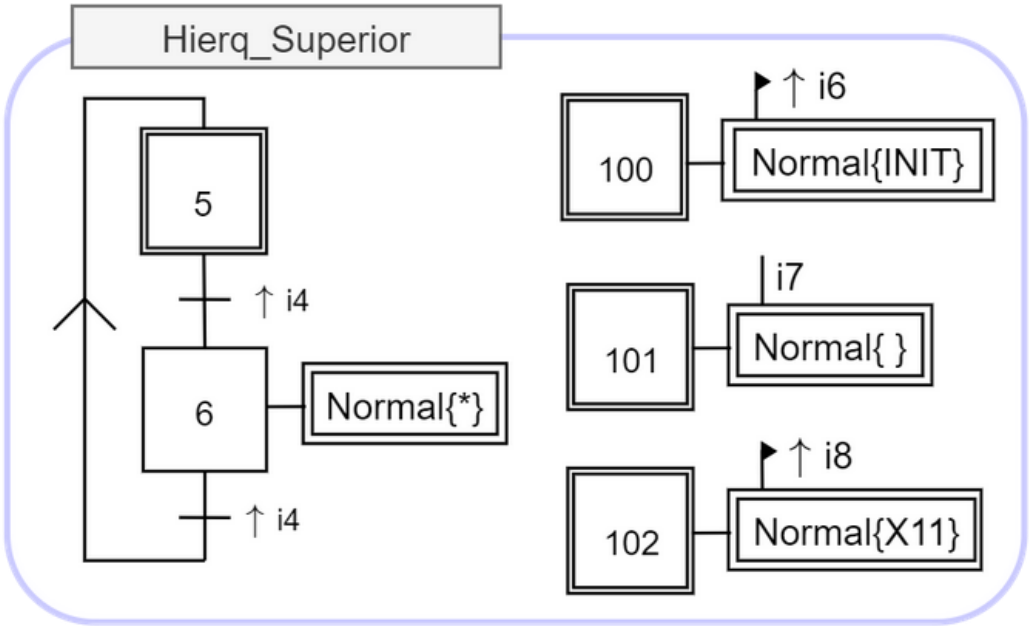
FEUPAutom v.5.50+











“FEUPAutom_Grafcet”
(incluindo Grafcet hierárquico)

Armando Sousa

- Fim -

27/04/2020