Experimental Physics and Industrial Control System (EPICS)

Sequencer and State Notation Language

Tutorial Slides

Bob Dalesio & Andy Kozubal

August 11, 1999

Outline

- What is state notation and what function does it serve
- Components of a state notation program
- Building, running and debugging a state notation program
- Additional Features
- Some Notes on the Runtime Sequencer

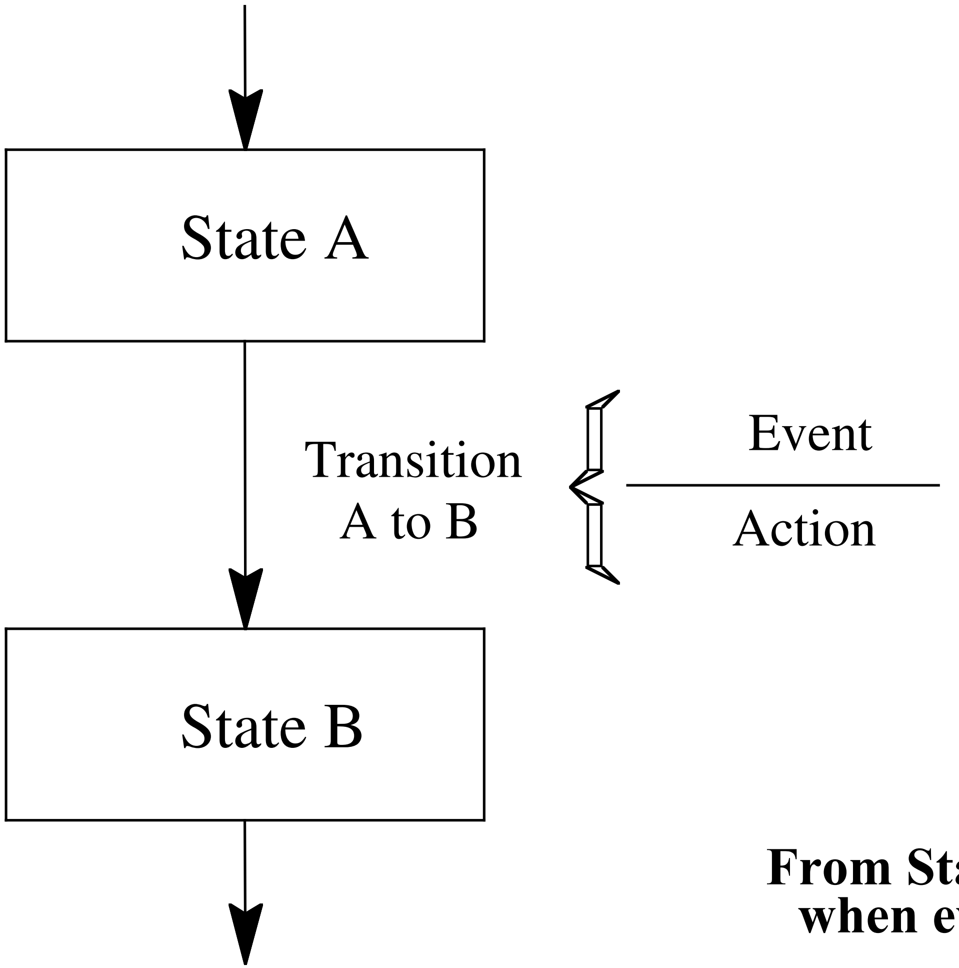
Purpose

- A language to facilitate sequential programming in the EPICS real-time environment
- Fast execution - compiled code
- Programming interface to extend EPICS in the real-time environment
- Easy for first-time user to learn and apply

Common Uses of the State Notation Language

- Provide automated start-up sequences like vacuum or RF where subsystems need coordination
- Provide fault recovery or transition to a safe state
- Provide access to the Unix file system for save/restore or restoration of parameters on reboot
- Provide automatic calibration of equipment

State Transition Diagram

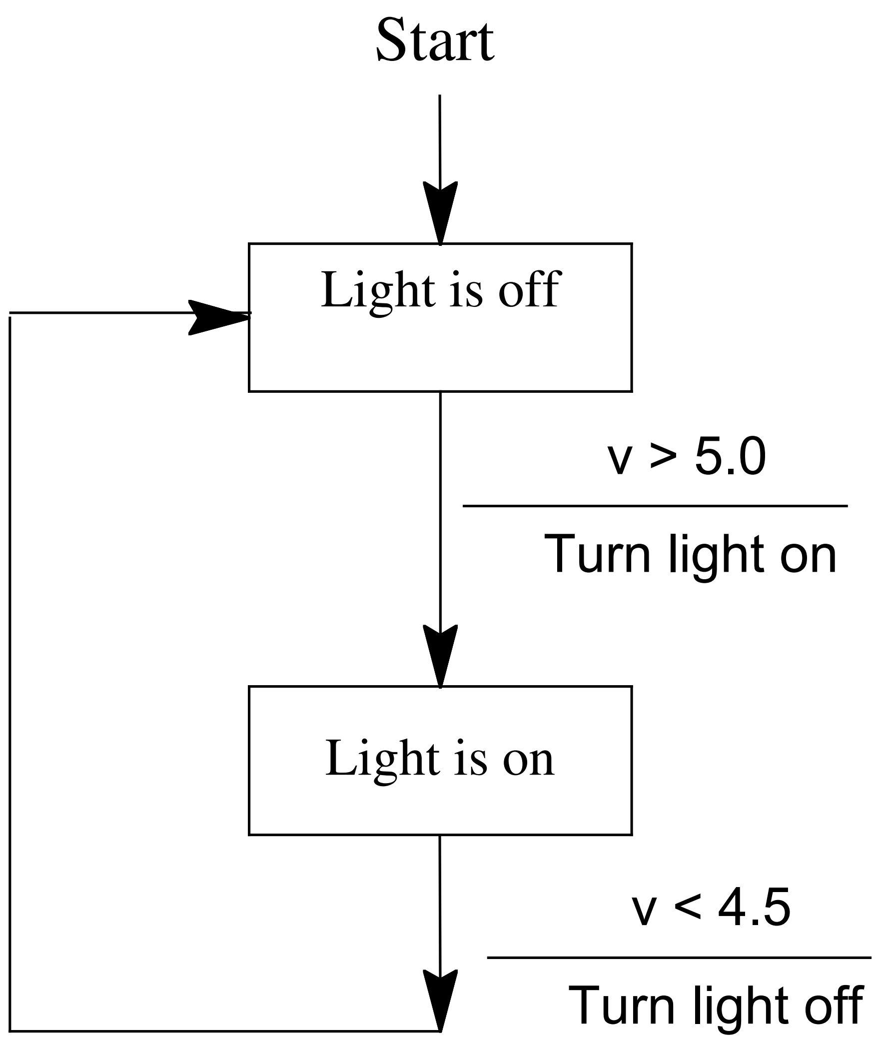


From State A:
when event occurs

perform action

then enter state B

Example of a STD



State Definitions and State Transitions

```
state light_off
{
        when (v > 5.0)
        {
                /*
                * turn light on
                */
        } state light_on
}

state light_on
{
        when (v < 4.5)
        {
                /*
                * turn light off
                */
        } state light_off
}
```

Channel Access in SNL

Variables assigned to a channel

```
short       light;
assign      light to "PS1:Lt_High";

                /* turn light on */
                light = TRUE;
                pvPut(light);

                /* turn light off */
                light = FALSE;
                pvPut(light);
```

Asynchronous Channel Access

The "monitor" concept

```
float       V1;
assign      V1 to "PS1:Vout;

monitor     V1;

            when (V1 > 5.0) { . . .
```

A Complete Program

```
program example
float           V1;
assign          V1 to "PS1:Vout;
monitor   V1;
short           light;
assign          light to "PS1:Lt_High";
ss volt_check
{
        state light_off
        {
                when (V1 > 5.0)
                {
                        /* turn light on */

                        light = TRUE;
                        pvPut(light);
                } state light_on
        }

        state light_on
        {
                when (V1 < 4.5)
                {
                        /* turn light off */
                        light = FALSE;
                        pvPut(light);
                } state light_off
        }
}
```

SNL: General Structure and Syntax

```
program program_name
declarations
ss state_set_name
{
        state state_name
        {
                when (event)
                {
                        action_statements
                } state new_state
                when...
        state state_name
        {
                ....
        }
```

Declarations

```
int      variable_name;
short    variable_name;
long     variable_name;
char     variable_name;
float    variable_name;
double   variable_name;
string   variable_name; /* this is used for db strings */

int      variable_name[array_length];
short    variable_name[array_length];
long     variable_name[array_length];
char     variable_name[array_length];
float    variable_name[array_length];
double   variable_name[array_length];

assign  var_name to database_name;
*assign         var_name[] = {db_name1, db_name2, db_name3};
monitor var_name;
```

Events

when (*any C expression*)

Possible events:

Change in value of a variable

A time delay:

delay(*delay_in_seconds*)

An internally generated event (event flag):

efTest(*event_flag_name*)

efTestAndClear(*event_flag_name*)

Change in the channel access connection status.

Actions

any C expression

%% escape one line of C code

%{
escape any number of lines of C code
}%

Built-in action function:

- **pvPut** (variable_name);
- **pvGet** (variable_name);
- **efSet** (event_flag_name);
- **efClear** (event_flag_name);

Event flags

1. Declaration:

evflag event_flag_name;

2. Communicate between state sets:

    efSet(event_flag_name);
    efTest(event_flag_name)
    efClear(event_flag_name)
    efTestAndClear(event_flag_name)

3. Notification when a monitor completes:

sync   variable_name event_flag_name;

    efTest(event_flag_name);

Building a state program

1. Use editor to build the source file: file name must end with ".st", e.g. "example.st".

2. Compile the state program to produce C code:

   ```
   snc  example.st
   ```

   This produces the file "example.c".

3. Compile "example.c" with the C compiler:

   ```
   make example.o
   ```

This produces the file "example.o", which is ready to be loaded by VxWorks.

The C preprocessor is generally used before snc is executed.

An applications Makefile simplifies these steps.

Executing a state program

Assume that VxWorks is running in an IOC and the proper database is loaded. Also, assume the UNIX working directory is the same as where to IOC was booted.

1. Telnet to the IOC:

   telnet ts1
   log in
   ts1> *you should get a prompt*

2. Load the object module:

   ts1> ld < example.o

3. Execute the state program:

   ts1> seq &example *this is the program name*

   This will create one task for each state set.

4. Exercise the program.

5. Print a summary of state programs

   ts1> seqShow

6. Delete any one of the tasks that were created in step 3.

   ts1> td "example"

Hints for debugging a state program

Currently there is no source-level debugger for sequencer.

1. Use printf statements in program:
   printf("entering state: light_on");
2. Manually enter database values using CAU:
   cau: put hv03:temp1 150
3. Print database values using CAU:
   cau: get hv03:temp1
   150.00
4. Use special state program query commands:
   seqShow
   displays information on all running state programs
   seqShow "example"
   displays detailed information on program
   seqChanShow "example"
   displays information on all channels
5. Use spy to find infinite loops with no delays

Example of seqShow output

```
seqTest> seqShow
Program Name    Task ID   Task Name     SS Name

mixTest            26      mixTest       generate_waveform
                   29      mixTest_1       level_det
                   30      mixTest_2       test_status
                   31      mixTest_3       periodic_read
                   32      mixTest_4       mon_array

mixTestX        33      A_seq         alpha

conTest         35      conTest       conTest

value = 0 = 0x0
```

Example of seqShow Output

```
seqTest> seqShow "mixTest"
State Program: "mixTest"
initial task id=26=0x1a

task priority=1
    number of state sets=5
    number of channels=6
    number of channels connected=6
    options: async=0, debug=1, reent=1, conn=1, newef=1
    log file fd=16
    log file name="mix.log"

Hit RETURN to continue
    State Set: "generate_waveform"
    task name=mixTest;    id=26=0x1a
    First state = "start"
    Current state = "gen_wf"
    Previous state = "gen_wf"
    Time state was entered = 269.4 seconds)
    Elapsed time since state was entered = 0.0 seconds)
    Number delays queued=1
    timeout[0] = 269.5 seconds
Hit RETURN to continue
...........................
```

Additional Features

1. Connection management:

   when (pvConnectCount() != pvChannelCount())
   when (pvConnected(Vin))

2. Macros:

   assign Vout to "{unit}:OutputV";
   (must use the +r compiler options for this)
   ts1> seq &example, "unit=HV01"

3. Compiler options:

   +r make program reentrant
   -c don't wait for all channel connections
   +a asynchronous pvGet()
   -w don't print compiler warnings

4. Pass parameters to programs at run time:

   pStr = macValueGet("bias");
   ts1> seq &example, "bias = 2.55"

5. Access to alarm status and severity:

   pvStatus(var_name)
   pvSeverity(var_name)

The Run-Time Sequencer

1. The sequencer executes the state program in the VxWorks environment.
2. The sequencer supports the event-driven execution; no polling needed.
3. Each state set becomes a VxWorks task.
4. The sequencer manages connections to database channels through "channel access".
5. The sequencer provides support for channel access (put, get, and monitor).
6. The sequencer supports asynchronous execution of delay and event flag functions.
7. Only one copy (object module) of the sequencer is required on each IOC.
8. Query commands display information about executing state programs.