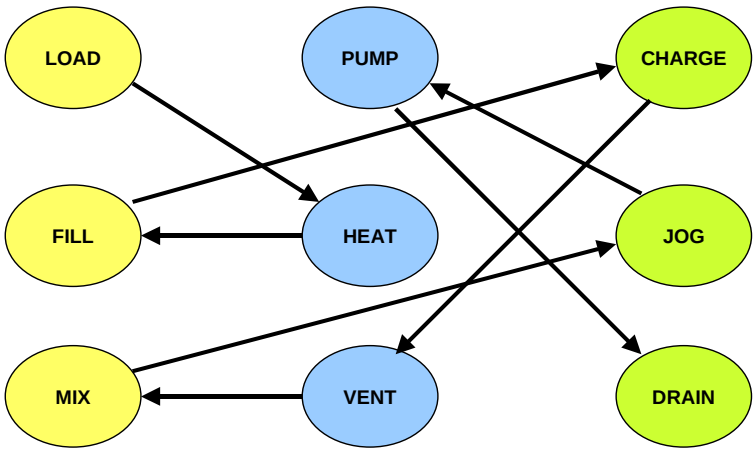
HC900 Hybrid Controller

When you need more than just discrete control

Sequencer Function Block – Product Note



Background:

The need to control a sequence of operation is a very common control requirement in industrial equipment today. Sequence control can be a very rigid series of inter-related events used to start-up or shut-down a unit process, or it can be a series of timed and process measurement dependent events that are executed to produce a final product. Sequences can be very simple with only timed or cascaded events that occur regardless process feedback, or they can be very complex with multiple nested default sequences programmed to occur only if process feedback indicates a need to take alternate actions.

When sequence control is used to produce final product, sequence variations are often required to allow the same equipment to be used to produce multiple types of product. In these applications the sequence is often partitioned into logical units to allow operators and supervisors to monitor the progress of the process using familiar terminology. Heat-up, cool-down, filling, venting, mixing and other similar terms are often used to describe the particular state the control equipment is executing. Variations in the product being processed can require changes to the sequence where particular states are bypassed, duplicated or executed in an alternate manner. When all of these requirements are combined in a single control specification, developing a suitable control strategy can be a demanding and sophisticated endeavor.

Problem Statement:

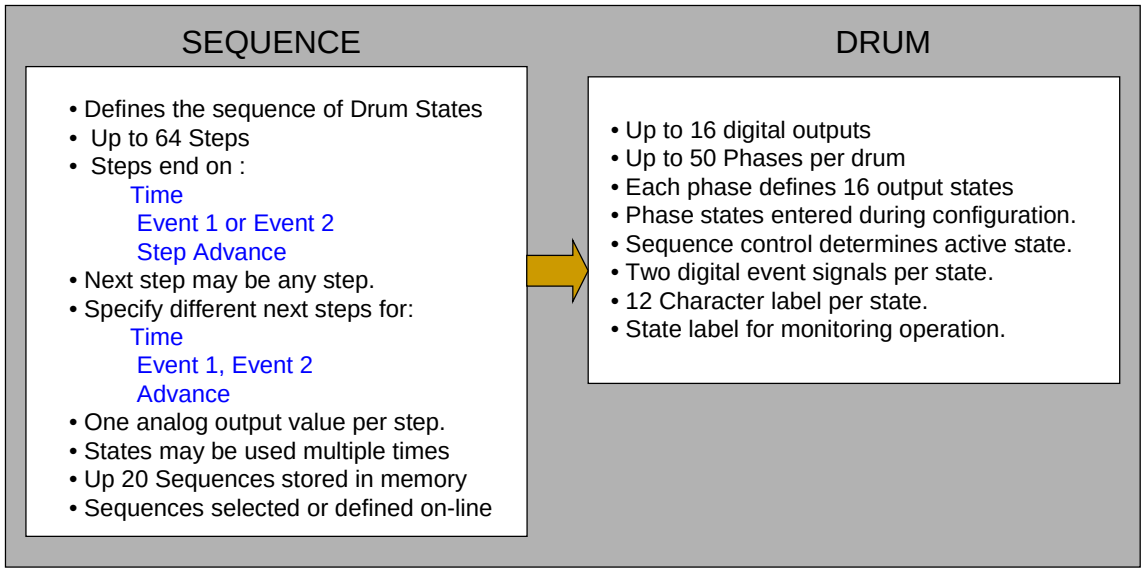
The execution of a control sequence requires the actuation or de-actuation of multiple digital outputs based on elapsed time or digital event inputs from process measurements or other digital status. The following are typical requirements for sequence control:

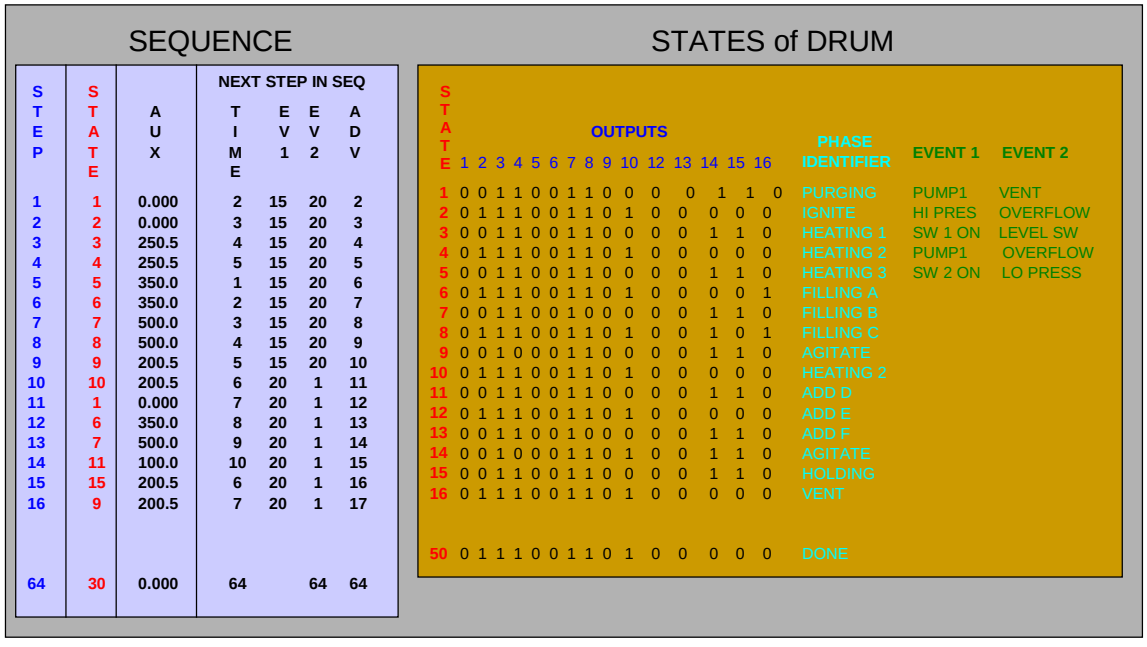
- The system should be able to automatically start the control sequence based on process conditions or support operator input to start and stop sequences when process requirements dictate.
- The control solution should allow easy selection of alternate sequences to support the processing of multiple types of products.

- The control solution should provide facilities to select alternate sequence actions based on process conditions or faults.
- Personalized state labels for the different sequence partitions should be supported to facilitate process monitoring at the user interface.
- Facilities should be provided to allow an operator to hold or advance a sequence when necessary.

Control Solution:

The Sequencer Function Block of the HC900 Controller provides attributes that support a wide range of sequence control applications. The architecture of the HC900 Sequencer provides two functional areas, the Sequence Control Functions and the Drum State Control functions. Drum States specify the digital outputs that will be on or off simultaneously. The sequence control function controls when a particular state is enabled.





STEP	STATE	AUX	NEXT STEP IN SEQ TIME	EV 1	EV 2	ADV
1	1	0.000	2	15	20	2
2	2	0.000	3	15	20	3
3	3	250.5	4	15	20	4
4	4	250.5	5	15	20	5
5	5	350.0	1	15	20	6
6	6	350.0	2	15	20	7
7	7	500.0	3	15	20	8
8	8	500.0	4	15	20	9
9	9	200.5	5	15	20	10
10	10	200.5	6	20	1	11
11	1	0.000	7	20	1	12
12	6	350.0	8	20	1	13
13	7	500.0	9	20	1	14
14	11	100.0	10	20	1	15
15	15	200.5	6	20	1	16
16	9	200.5	7	20	1	17
64	30	0.000	64		64	64

STATE	OUTPUTS 1	2	3	4	5	6	7	8	9	10	12	13	14	15	16	PHASE IDENTIFIER	EVENT 1	EVENT 2
1	0	0	1	1	0	0	1	1	0	0	0	0	1	1	0	PURGING	PUMP1	VENT
2	0	1	1	1	0	0	1	1	0	1	0	0	0	0	0	IGNITE	HI PRES	OVERFLOW
3	0	0	1	1	0	0	1	1	0	0	0	0	1	1	0	HEATING 1	SW 1 ON	LEVEL SW
4	0	1	1	1	0	0	1	1	0	1	0	0	0	0	0	HEATING 2	PUMP1	OVERFLOW
5	0	0	1	1	0	0	1	1	0	0	0	0	1	1	0	HEATING 3	SW 2 ON	LO PRESS
6	0	1	1	1	0	0	1	1	0	1	0	0	0	0	1	FILLING A		
7	0	0	1	1	0	0	1	0	0	0	0	0	1	1	0	FILLING B		
8	0	1	1	1	0	0	1	1	0	1	0	0	1	0	1	FILLING C		
9	0	0	1	0	0	0	1	1	0	0	0	0	1	1	0	AGITATE		
10	0	1	1	1	0	0	1	1	0	1	0	0	0	0	0	HEATING 2		
11	0	0	1	1	0	0	1	1	0	0	0	0	1	1	0	ADD D		
12	0	1	1	1	0	0	1	1	0	1	0	0	0	0	0	ADD E		
13	0	0	1	1	0	0	1	0	0	0	0	0	1	1	0	ADD F		
14	0	0	1	0	0	0	1	1	0	1	0	0	1	1	0	AGITATE		
15	0	0	1	1	0	0	1	1	0	0	0	0	1	1	0	HOLDING		
16	0	1	1	1	0	0	1	1	0	1	0	0	0	0	0	VENT		
50	0	1	1	1	0	0	1	1	0	1	0	0	0	0	0	DONE		

The descriptions that follow describe the implementation of sequence control in the HC900 controller beginning with a basic unmonitored timed sequence and increasing in functionality to address more demanding and interactive sequence control operations.

The HC900 controller supports the following sequence functions:

Sequence function blocks per controller	-	four (4)
Digital outputs per function block	-	16
States per sequence	-	50
Steps per sequence	-	64
Analog output values per sequence step	-	one (1)
Sequences stored in controller memory	-	20
Time units	-	Seconds or minutes
Digital event signals	-	two (2) per state
Update rate	-	25ms min.

Basic timed, unmonitored sequence:

SEQUENCE

STEP #	Time	TIME next step	EV1	EV2	ADV
1	0:10	**2**			
2	15:00	**3**			
3	1:30	**4**			
4	120:00	**5**			
5	5:00	**6**			
6	:15	**7**			
7	20:00	**8**			
8	2.00	**9**			
9	:05	**10**			
10	1:30				

STATES

OUTPUTS

State	1	2	3	4	5	6	7	8	9	10	12	13	14	15	16
1	0	0	1	1	0	0	1	1	0	0	0	0	1	1	0
2	0	1	1	1	0	0	1	1	0	1	0	0	0	0	0
3	0	0	1	1	0	0	1	1	0	0	0	0	1	1	0
4	0	1	1	1	0	0	1	1	0	1	0	0	0	0	0
5	0	0	1	1	0	0	1	1	0	0	0	0	1	1	0
6	0	1	1	1	0	0	1	1	0	1	0	0	0	0	1
7	0	0	1	1	0	0	1	0	0	0	0	0	1	1	0
8	0	1	1	1	0	0	1	1	0	1	0	0	1	0	1
9	0	0	1	0	0	0	1	1	0	0	0	0	1	1	0
10	0	1	1	1	0	0	1	1	0	1	0	0	0	0	0

Figure 3

The HC900 sequencer function block may be setup to control the on/off states of up to 16 digital outputs based on time. The operation is similar to a circular drum that indexes through a sequence of states (phases) like that found in a mechanical music box. The status for each of 16 digital outputs is programmed to be ON or OFF in each state. States are numbered from 1 to 50. A separate sequence function determines which state is enabled. The sequence function provides steps from 1 to 64. A time period may be entered in seconds or minutes for each step of the sequence function. A “time next step” is also specified for each step of the sequence that designates the step the sequence will advance to when the time expires.

To create a simple 10 step, 10 state sequence that starts with step 1, state 1 and advances to step 10, state 10 using time as the advance mechanism, simply enter the following data for the sequence function block and sequence control: See Figure 3.

Function Block entries:

The function block should have its outputs connected to the appropriate outputs in the control strategy. Enter the On/Off states for each of 16 outputs for the 10 states. These states are stored as part of the controller configuration when a configuration is downloaded.

Sequence Control entries:

Select a sequence number for the sequence to be configured and saved (1 to 20).
Select minutes or seconds for the time entry.
Enter the time value for each step of the sequence.
Designate a "time next step" step number for each step of the sequence. To create a once through sequence, designate the "time next steps" as 2 through 10 for steps 1 through 9. With this setup the next step will be the next logical step in the sequence.
Save the sequence.

Connect an "Analog Variable" to the NSEQ (Sequence Number) pin of the Sequencer function block. Specify the sequence number that was saved above as the variable value. This will automatically load the sequence into the function block on startup of the controller.

Connect a digital signal to the START input to the function block to control when the sequence is to begin.

Selecting a state:

The Sequence function in the previous section designates a "step time" and a "time next step" for each step of the sequence. The state number was assumed to be the same number as the step number. In actual setup, a state number must be entered for each step of the sequence. To have the states execute sequentially from 1 through 10 based on step numbers 1 through 10, each step would need a corresponding state number as follows:
Step 1 = State 1,
Step 2 = State 2,
Step 3 = State 3 ,

Step 10 = State 10

Changing the state sequence:

By supporting a state number for each step of the sequence, a state may be selected multiple times in the sequence. Since time is an attribute of the sequence, the state may be activated for a different time period each time it is selected. Example:
Step 1 = State 1, time = .10
Step 2 = State 2, time = 15.00
Step 3 = State 3, time = 1.3
Step 4 = State 2, time = 7.5

Non-sequential Steps:

In the above examples the "Time Next Step" value is set to the next sequential step in the sequencer. With this setup, when step 1 times out the sequence advances to step 2, when step 2 times out the sequence advances to step 3 and so on. Process variations can be made quickly by altering the "time Next Step" value. In the example below, step 3's "Time Next Step" value is changed from step 4 to step 7, causing the sequencer to skip steps 4, 5 and 6. The "Time Next Step" value can be any step in the sequence, including steps that have been previously executed.

SEQUENCE | **STATES**

STEP #	Time	TIME next step	EV1	EV2	ADV
1	0:10	2			
2	15:00	3			
3	1:30	7			
4	120:00	5			
5	5:00	6			
6	:15	7			
7	20:00	8			
8	2.00	9			
9	:05	10			
10	1:30				

OUTPUTS

State	1	2	3	4	5	6	7	8	9	10	12	13	14	15	16
1	0	0	1	1	0	0	1	1	0	0	0	0	1	1	0
2	0	1	1	1	0	0	1	1	0	1	0	0	0	0	0
3	0	0	1	1	0	0	1	1	0	0	0	0	1	1	0
4	0	1	1	1	0	0	1	1	0	1	0	0	0	0	0
5	0	0	1	1	0	0	1	1	0	0	0	0	1	1	0
6	0	1	1	1	0	0	1	1	0	1	0	0	0	0	1
7	0	0	1	1	0	0	1	0	0	0	0	0	1	1	0
8	0	1	1	1	0	0	1	1	0	1	0	0	1	0	1
9	0	0	1	0	0	0	1	1	0	0	0	0	1	1	0
10	0	1	1	1	0	0	1	1	0	1	0	0	0	0	0

Figure 4

Using Events:
In addition to time as a method of ending a step, each state of the sequencer can be configured to accept two different digital events to terminate the step. The events support a corresponding “Event 1 Next Step” and “Event 2 Next Step” value in the sequence configuration. When both time and events are configured for a step, the first occurrence of either event or elapsed time will cause the sequencer to advance to the appropriate next step.

The digital signals that represent events are the property of the states that are enabled by the sequencer step. Each state can have two digital signals, one for event 1 and one for event 2, that when ON (logic 1) terminate the current sequencer step. Different digital signals may be used for each state to represent event 1 and event 2.

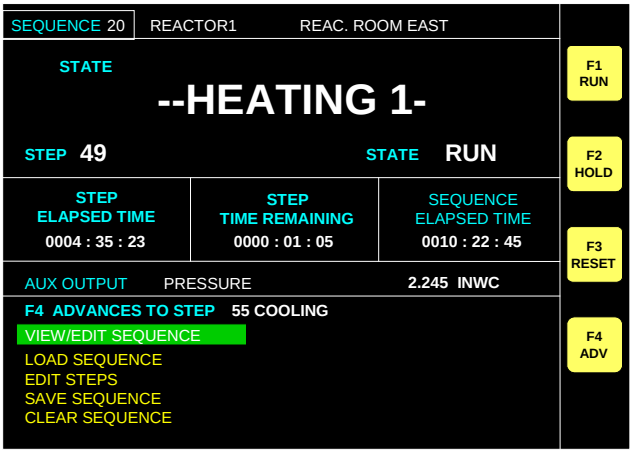
An example using this feature would be a digital output from a state that is enabling a pump to fill a tank. Under normal operation the pump would fill the tank in less than 10 minutes. A level sensor on the tank would normally provide the digital event needed to terminate the step and advance the sequence to the next step. If, however, a problem occurred with the pump and it took longer than 10 minutes for the full event to occur, an elapsed time could expire and cause the sequencer to jump to an abort or shut-down portion of the sequence.

Using Manual Advance:
The flexibility provided through the independent next step values of the Step Time, Event 1, and Event 2 functions creates multiple next step options when the manual advance key is depressed. To allow the user to select an appropriate action for the manual advance OI action or function block digital advance input, a separate user configurable “Advance Next Step” value may be entered for each step of the sequencer.

Dynamic step advance:
The Sequencer function block supports an advance to a programmatically specified step. To execute this function, simply connect the function block source of the next step value to the “Next Step input pin (NSTEP) of the function block and apply an enable (logic1) to the “SET” input pin of the sequencer function block.

Changing a Sequence:
The HC900 controller allows on-board storage of up to 20 sequences that are selected by name or number and loaded into one of four available sequencers. Function block input pins also allow automated loading of sequences by number. In addition, sequences can be created or modified from the 1042 Operator Interface using dedicated sequencer displays.

Monitoring a Sequence:
The previous sequencer examples used step and state numbers to provide information on the sequencer progress. This is often acceptable for sequences that execute in the background and status is only important for diagnostic purposes. When the sequence status is important information for planning and scheduling production activities, this level of detail may not be acceptable. The HC900 sequencers provide a 12 character label for each state of the sequence, plus operator displays that indicate time remaining in a step and total sequence elapsed time. See sample display that follows:



Integrating the Sequencer:
The Sequencer function block can be easily integrated into a control strategy with dedicated block input pins to start, stop, hold, advance, jog, and reset a sequence. Additional input pins are provided to automatically load a new sequence or to specify a starting step for the sequence. Output pins include 16 digital outputs controlled by the sequence plus time status, state number, step number and an auxiliary analog output value that may be configured to provide a new value for each step of the sequence.

Summary:
Although the HC900 sequencer can duplicate many of sequential control operations found in typical PLC Drum Sequencer algorithms, the robust sequence control, monitoring displays and sequence storage features of the HC900 Controller provide capabilities that are not easily duplicated. Add to this an easy to setup and operate environment and the HC900 sequence control algorithm becomes a truly differentiated feature for this exceptional control product.