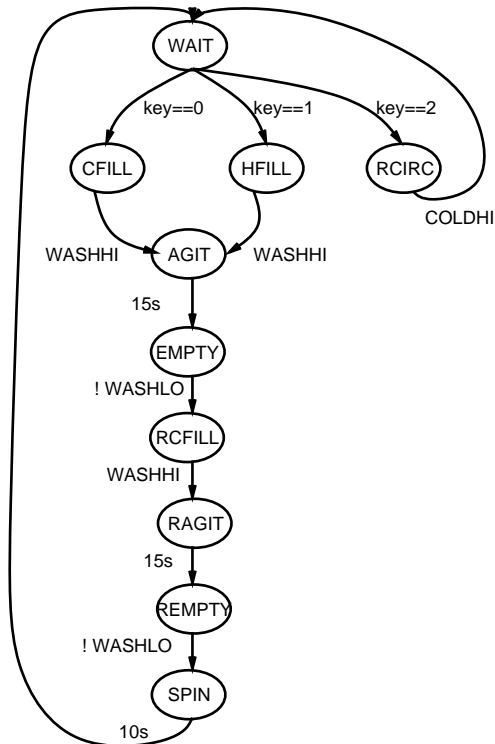


Solutions to Lab 4

The state machine can be drawn as follows. In the diagram the condition WASHHI means the water level has reached the washtub high-level sensor and the condition ! WASHLO means the water level is below the washtub low-level sensor. The condition 15s means the indicated time (15 seconds) has expired. The condition key==1 means the '1' key was pressed.



The following table shows the outputs for each state.

State	Display	Pump Output
WAIT	CYCLE?	none
CFILL	COLDWASH	COLDFILL
HFILL	HOTWASH	HOTFILL
AGIT	xWASH (1)	SPIN (2)
EMPTY	xWASH (1)	EMPTY
RCFILL	RINSE	COLDFILL
RAGIT	RINSE	SPIN (2)
REMPY	RINSE	EMPTY
SPIN	SPIN	SPIN (3)
RCIRC	RECYCLE	RECYCLE

Notes:

- (1) xWASH is either COLDWASH or HOTWASH depending on the cycle
- (2) SPIN is on intermittently for 5 cycles of 1 second on and 2 seconds off
- (3) SPIN is on continuously for 10 seconds

The state transition table would normally have one column for each input. To reduce the table to a manageable width the table below shows the input signal and the value required for a transition. All other inputs are assumed to be "don't care" (X).

In the table below the notation WASHHI means that the WASHHI sensor detects water (has value 0) and ! WASHLO means that the sensor does not detect water.

current state	input conditions	next state
WAIT	key == 0	CFILL
WAIT	key == 1	HFILL
WAIT	key == 2	RCIRC
WAIT	no key	WAIT
CFILL	WASHHI	AGIT
CFILL	! WASHHI	CFILL
HFILL	WASHHI	AGIT
HFILL	! WASHHI	HFILL
AGIT	after 15 s	EMPTY
AGIT	before 15 s	AGIT
EMPTY	! WASHLO	RCFILL
EMPTY	WASHLO	EMPTY
RCFILL	WASHHI	RAGIT
RCFILL	! WASHHI	RCFILL
RAGIT	after 15 s	REMPY
RAGIT	before 15 s	RAGIT
REMPY	! WASHLO	SPIN
REMPY	WASHLO	REMPY
SPIN	after 10 s	WAIT
SPIN	before 10 s	SPIN
RCIRC	COLDHI	WAIT
RCIRC	! COLDHI	RCIRC

An implementation of the above state machine in C would be as follows:

```

/*
  APSC 380 Lab 4 - Sample Solution
  Ed Casas, October 30 1997
*/

/* The display() and rdkbd() are in lab2.c */

#include "lab2.c"

#define PUMPS          0x51
#define RECYCLE        0x20
#define HOTFILL        0x10
#define COLDFILL       0x08
#define EMPTY         0x04
#define SPIN           0x02

#define SENSORS        0x52
#define WASHHI         0x80
#define WASHLO         0x40
#define COLDDHI        0x20

#define ENABLE         0x53
#define MODULEOFF      0x80

#define AGCYCLES       5
#define AGONTIME        1
#define AGOFFTIME      2

#define SPINTIME       10

#define COLDKEY        '0'
#define HOTKEY         '1'
#define RECYCLEKEY     '2'

#define S_WAIT         1
#define S_CFILL        2
#define S_HFILL        3
#define S_AGIT         4
#define S_EMPTY        5
#define S_RCFILL       6
#define S_RAGIT        7
#define S_REEMPTY      8
#define S_SPIN         9
#define S_RCIRC        10

/* Return non-zero if water is at 'sensor' level */

int level ( int sensor )
{
  return ( speak ( SENSORS ) & sensor ) == 0 ;
}

/* Washing machine simulator */

main ()
{
  int state, c, i ;

  spoke ( ENABLE, 0 ) ;          /* enable outputs */
  state = S_WAIT ;

```

```

while ( 1 ) {

  if ( state == S_WAIT ) {      /* wait for command */

    display ( "CYCLE? " ) ;
    spoke ( PUMPS, 0 ) ;

    c = rdkbd () ;
    if ( c == COLDKEY ) {
      state = S_CFILL ;
    } else if ( c == HOTKEY ) {
      state = S_HFILL ;
    } else if ( c == RECYCLEKEY ) {
      state = S_RCIRC ;
    }

  } else if ( state == S_CFILL ) {

    /* cold fill for wash */

    display ( "COLDWASH" ) ;
    spoke ( PUMPS, COLDFILL ) ;

    if ( level ( WASHHI ) ) {
      state = S_AGIT ;
    }

  } else if ( state == S_HFILL ) {

    /* hot fill for wash */

    display ( "HOTWASH " ) ;
    spoke ( PUMPS, HOTFILL ) ;

    if ( level ( WASHHI ) ) {
      state = S_AGIT ;
    }

  } else if ( state == S_AGIT ) {

    /* agitate */

    for ( i=0 ; i<AGCYCLES ; i++ ) {
      spoke ( PUMPS, SPIN ) ;
      sleep ( AGONTIME ) ;
      spoke ( PUMPS, 0 ) ;
      sleep ( AGOFFTIME ) ;
    }

    state = S_EMPTY ;

  } else if ( state == S_EMPTY ) {

    /* empty wash water */

    spoke ( PUMPS, EMPTY ) ;

    if ( ! level ( WASHLO ) ) {
      state = S_RCFILL ;
    }

  } else if ( state == S_RCFILL ) {

    /* cold fill for rinse */

    display ( "RINSE " ) ;
    spoke ( PUMPS, COLDFILL ) ;

```

```

    if ( level ( WASHHI ) ) {
        state = S_RAGIT ;
    }

} else if ( state == S_RAGIT ) {

    /* rinse agitate */

    spoke ( PUMPS, SPIN ) ;

    sleep ( SPINTIME ) ;
    state = S_EMPTY;

} else if ( state == S_EMPTY ) {

    /* empty rise water */

    spoke ( PUMPS, EMPTY ) ;

    if ( ! level ( WASHLO ) ) {
        state = S_SPIN ;
    }

} else if ( state == S_SPIN ) {

    /* spin */

    display ( "SPIN      " ) ;
    spoke ( PUMPS, SPIN ) ;

    sleep ( 10 ) ;
    state = S_WAIT;

} else if ( state == S_RCIRC ) {

    /* recirculate drain tank water */

    display ( "RECYCLE " ) ;
    spoke ( PUMPS, RECYCLE ) ;

    if ( level ( COLDHI ) ) {
        state = S_WAIT ;
    }

}

} /* end of while() loop */
}

```