Drink Machine—State Machine Version

The next design is a vending control unit for a soft drink vending machine. The circuit reads signals from a coin-input unit and sends outputs to a change-dispensing unit and a drink-dispensing unit.

Input signals from the coin-input unit are `nickel_in` (nickel deposited), `dime_in` (dime deposited), and `quarter_in` (quarter deposited).

Outputs to the vending control unit are `collect` (collect coins) to the coin-input unit, `nickel_out` (nickel change) and `dime_out` (dime change) to the change-dispensing unit, and `dispense` (dispense drink) to the drink-dispensing unit.

The price of a drink is 35 cents. The first Verilog description for this design uses a state-machine description style. The description includes the `// synopsys` directive, which enables Design Compiler to extract an equivalent state machine.

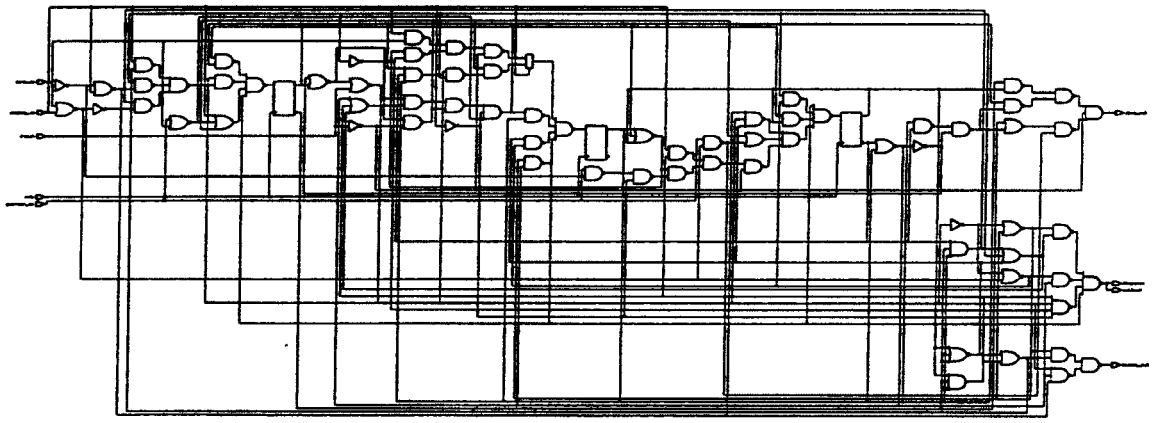
Example A-3 Drink Machine—State Machine Version

```
'define vend_a_drink {D,dispense,collect} = {IDLE,2'b11}

module drink_machine(nickel_in, dime_in, quarter_in,
                     collect, nickel_out, dime_out,
                     dispense, reset, clk) ;

   parameter IDLE=0,FIVE=1,TEN=2,TWENTY_FIVE=3,
             FIFTEEN=4,THIRTY=5,TWENTY=6,OWE_DIME=7;

   input  nickel_in, dime_in, quarter_in, reset, clk;
   output collect, nickel_out, dime_out, dispense;

   reg collect, nickel_out, dime_out, dispense;
   reg [2:0] D, Q; /* state */
// synopsys state_vector Q

always @ ( nickel_in or dime_in or quarter_in or reset )
      begin
         nickel_out = 0;
         dime_out   = 0;
         dispense   = 0;
         collect    = 0;

         if ( reset ) D = IDLE;
         else begin
            D = Q;

            case ( Q )
            IDLE:
               if (nickel_in)       D = FIVE;
               else if (dime_in)    D = TEN;
               else if (quarter_in) D = TWENTY_FIVE;

            FIVE:
               if(nickel_in)        D = TEN;
               else if (dime_in)    D = FIFTEEN;
               else if (quarter_in) D = THIRTY;

            TEN:
               if (nickel_in)       D = FIFTEEN;
               else if (dime_in)    D = TWENTY;
               else if (quarter_in) 'vend_a_drink;

            TWENTY_FIVE:
               if( nickel_in)       D = THIRTY;
               else if (dime_in)    'vend_a_drink;
               else if (quarter_in) begin
                  'vend_a_drink;
                  nickel_out = 1;
                  dime_out = 1;
               end
```

Example A-3 (continued) Drink Machine—State Machine Version

```
                    FIFTEEN:
                       if (nickel_in)        D = TWENTY;
                       else if (dime_in)     D = TWENTY_FIVE;
                       else if (quarter_in) begin
                          'vend_a_drink;
                          nickel_out = 1;
                       end

                    THIRTY:
                       if (nickel_in)        'vend_a_drink;
                       else if (dime_in)     begin
                          'vend_a_drink;
                          nickel_out = 1;
                       end
                       else if (quarter_in) begin
                          'vend_a_drink;
                          dime_out = 1;
                          D = OWE_DIME;
                       end

                    TWENTY:
                       if (nickel_in)        D = TWENTY_FIVE;
                       else if (dime_in)     D = THIRTY;
                       else if (quarter_in) begin
                          'vend_a_drink;
                          dime_out = 1;
                       end

                    OWE_DIME:
                       begin
                          dime_out = 1;
                          D = IDLE;
                       end

                    endcase
                end
            end

            always @ (posedge clk ) begin
                Q = D;
            end
            endmodule
```

Example A-3 (continued) Drink Machine—State Machine Version



Drink Machine—Count Nickels Version

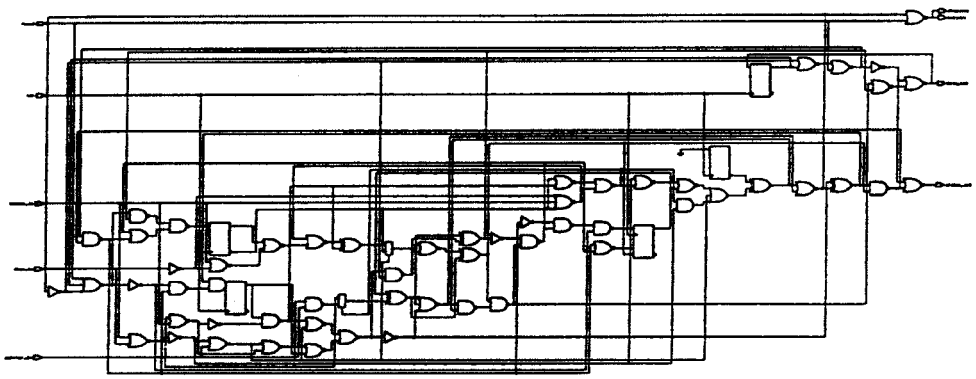
This example uses the same design parameters as the preceding example, with the same input and output signals. In this version, a counter counts the number of nickels deposited. This counter is incremented by 1 if the deposit is a nickel, by 2 if it's a dime, and by 5 if it's a quarter.

Example A-4 Drink Machine—Count Nickels Version

```
module drink_machine(nickel_in,dime_in,quarter_in,collect,
      nickel_out,dime_out,dispense,reset,clk);

   input nickel_in, dime_in, quarter_in, reset, clk;
   output nickel_out, dime_out, collect, dispense;

   reg nickel_out, dime_out, dispense, collect;
   reg [3:0] nickel_count, temp_nickel_count;
   reg temp_return_change, return_change;

      always @ ( nickel_in or dime_in or quarter_in or
            collect or temp_nickel_count or
            reset or nickel_count or return_change) begin
         nickel_out = 0;
         dime_out   = 0;
         dispense   = 0;
         collect    = 0;
         temp_nickel_count = 0;
         temp_return_change = 0;

         // Check whether money has come in
         if (! reset) begin
            temp_nickel_count = nickel_count;
            if (nickel_in)
               temp_nickel_count = temp_nickel_count + 1;
            else if (dime_in)
               temp_nickel_count = temp_nickel_count + 2;
            else if (quarter_in)
               temp_nickel_count = temp_nickel_count + 5;

         // correct amount deposited??
         if (temp_nickel_count >= 7) begin
            temp_nickel_count = temp_nickel_count - 7;
            dispense = 1;
            collect = 1;
         end
         // return change
         if (return_change || collect) begin
            if (temp_nickel_count >= 2) begin
               dime_out = 1;
               temp_nickel_count = temp_nickel_count - 2;
               temp_return_change = 1;
            end

            if (temp_nickel_count == 1) begin
               nickel_out = 1;
               temp_nickel_count = temp_nickel_count - 1;
            end
         end
      end
   end
```

Example A-4 (continued) Drink Machine—Count Nickels Version

```
        always @ (posedge clk ) begin
           nickel_count = temp_nickel_count;
           return_change = temp_return_change;
        end
    endmodule
```



Carry-Lookahead Adder

This example shows how to build a 32-bit carry-lookahead adder. The adder is built by partitioning the 32-bit input into eight slices of four bits each. The PG module computes *propagate* and *generate* values for each of the eight slices.

Propagate (output P from PG) is 1 for a bit position if that position propagates a carry from the next lower position to the next higher position. *Generate* (output G) is 1 for a bit position if that position generates a carry to the next higher position, regardless of the carry-in from the next lower position.

The carry-lookahead logic reads the carry-in, propagate, and generate information computed from the inputs. It computes the carry value for each bit position. This logic makes the addition operation just an XOR of the inputs and the carry values.