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Embedded Systems Design

ELEC3042 EMBEDDED SYSTEMS

Lecture 4

Computer Programs

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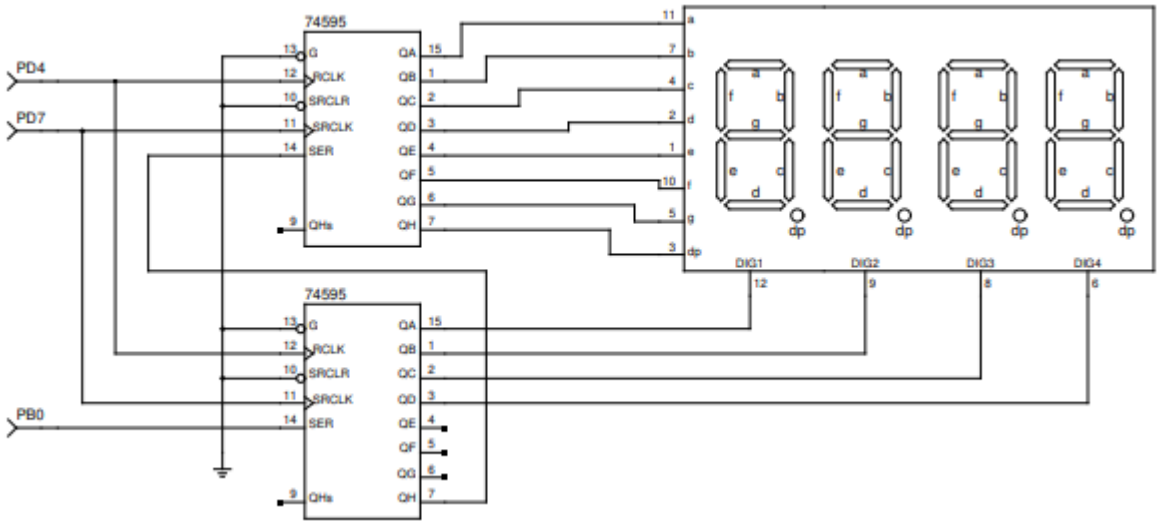
- Are step-by-step instructions for a computer to solve a problem
- Most problems are difficult to solve all at once. Begin by decomposing the problem into smaller parts
  - For each part, identify the input(s) and output(s)
  - Identify the steps that transform the input(s) into output(s)
  - Write the code to instruct the computer how to transform the input to output (usually as a function)
- Once you have solved all the smaller parts, combine them together to solve the overall problem

7-Segment Display

- Allow alphanumeric characters to be displayed with simple hardware
- HW-262 has four 7-segment displays connected to two 8-bit shift registers in series to form a 16-bit shift register
  - 8 bits are used to turn on/off the segments
  - 4 bits are used to turn on/off the digits
  - 4 bits are unused
- Shift register is controlled via 3 lines
  - Data (PB0) – the 16 control bits
  - Clock (PD7) – data shifts into registers on rising edge
  - Latch (PD4) – latches data to shift register output to be displayed



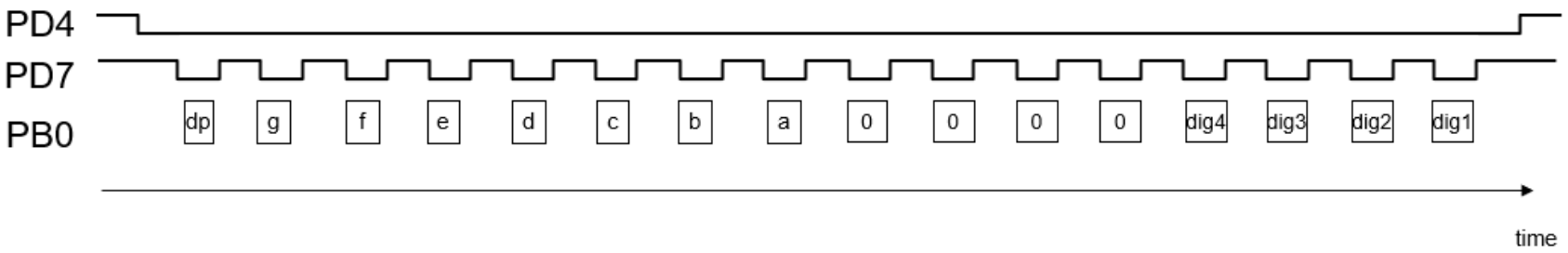
- Turn on/off a segment by sending a low/high voltage (active low)
- Select a digit by setting the corresponding bit high
- To show a four-digit number, we have to time multiplex the display

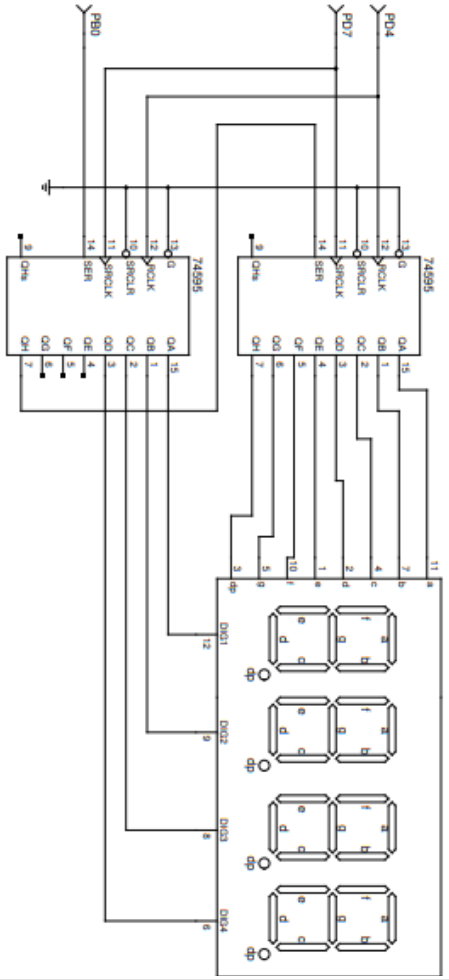
Exercise

WRITE A PROGRAM TO SHOW A FOUR-DIGIT NUMBER

- Break the problem into parts
- For each part, identify its inputs and outputs

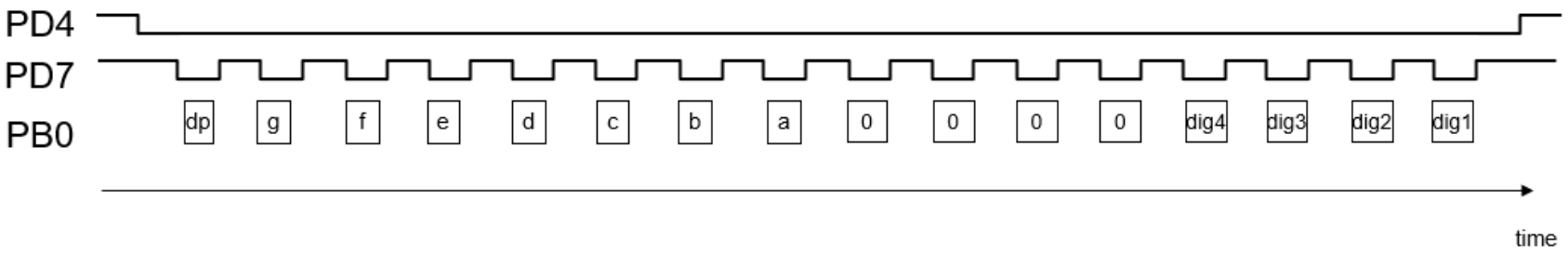
Showing a single character

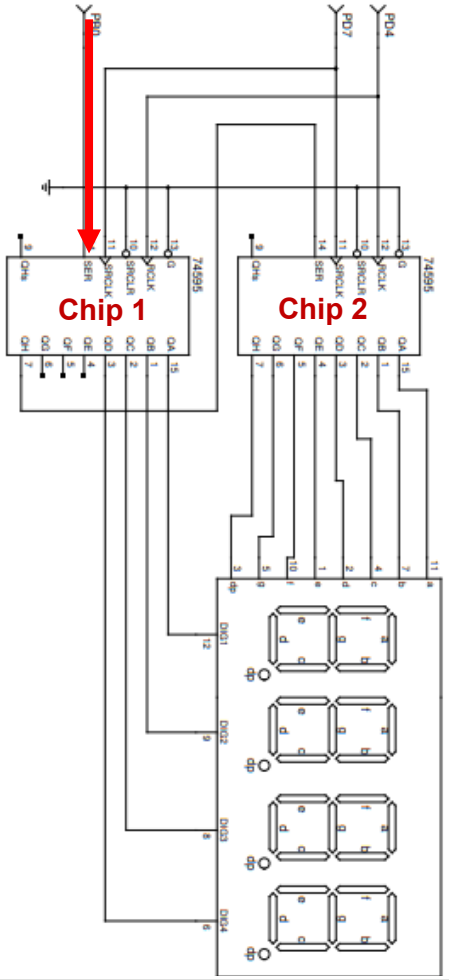




Showing a single character

AT EACH 0 -> 1 TRANSITION OF PD7, A NEW BIT IS CLOCKED IN

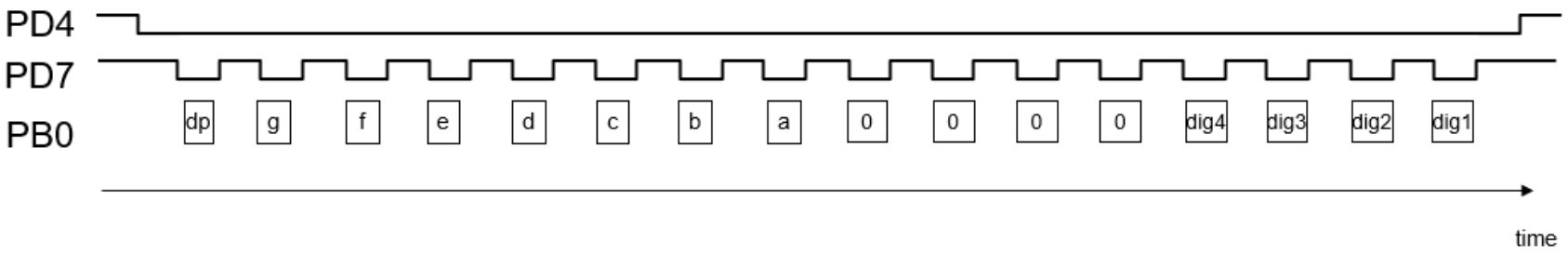


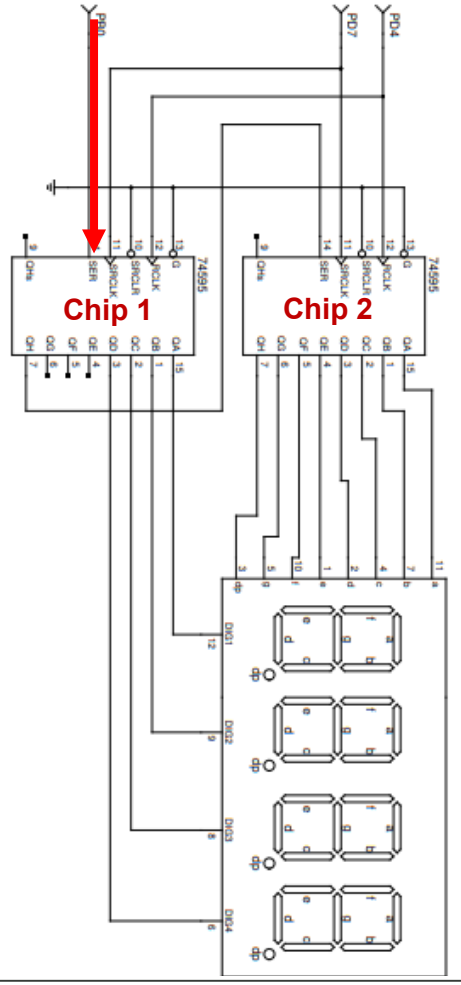


Chip 1								Chip 2							
QA	QB	QC	QD	QE	QF	QG	QH	QA	QB	QC	QD	QE	QF	QG	QH
dp															

Showing a single character

AT EACH 0 -> 1 TRANSITION OF PD7, A NEW BIT IS CLOCKED IN

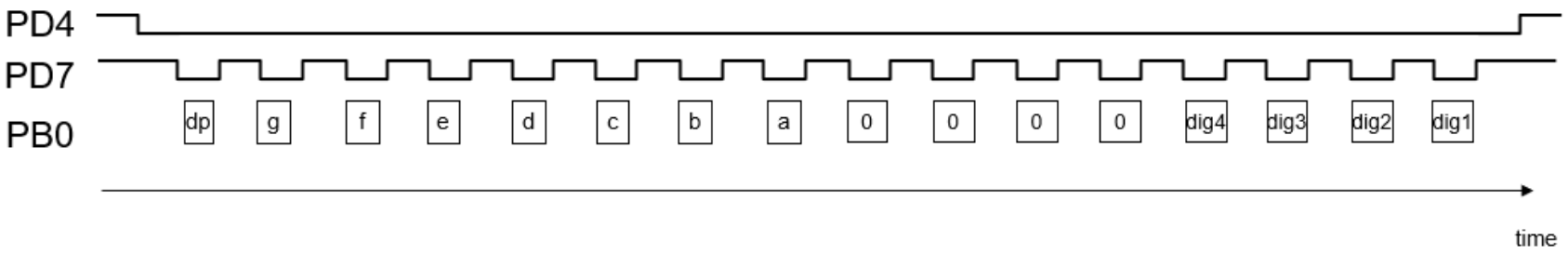


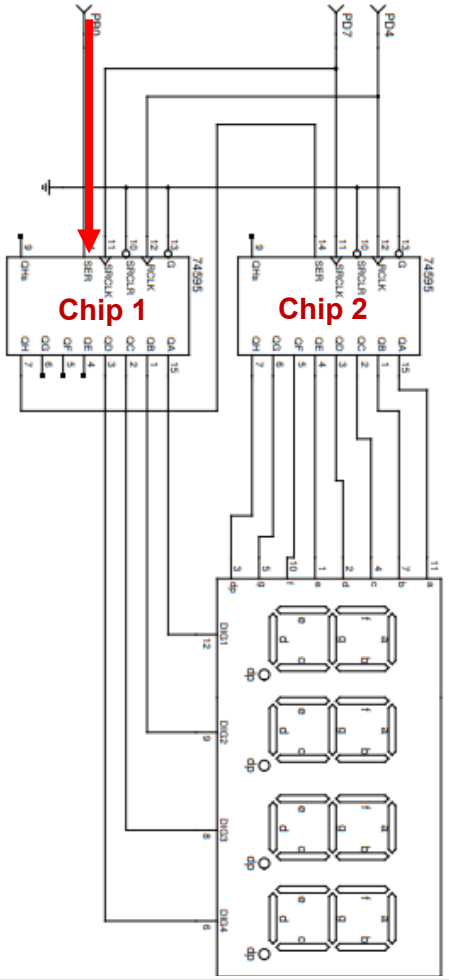


Chip 1								Chip 2							
QA	QB	QC	QD	QE	QF	QG	QH	QA	QB	QC	QD	QE	QF	QG	QH
g	dp														

Showing a single character

AT EACH 0 -> 1 TRANSITION OF PD7, A NEW BIT IS CLOCKED IN

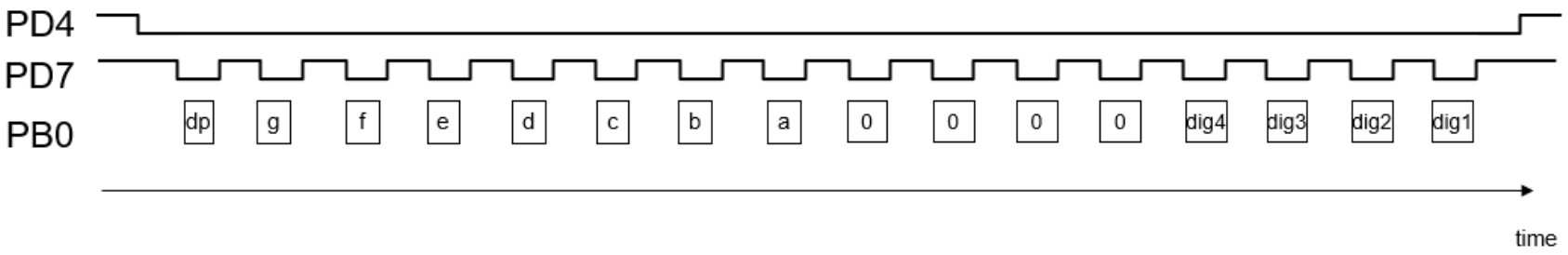


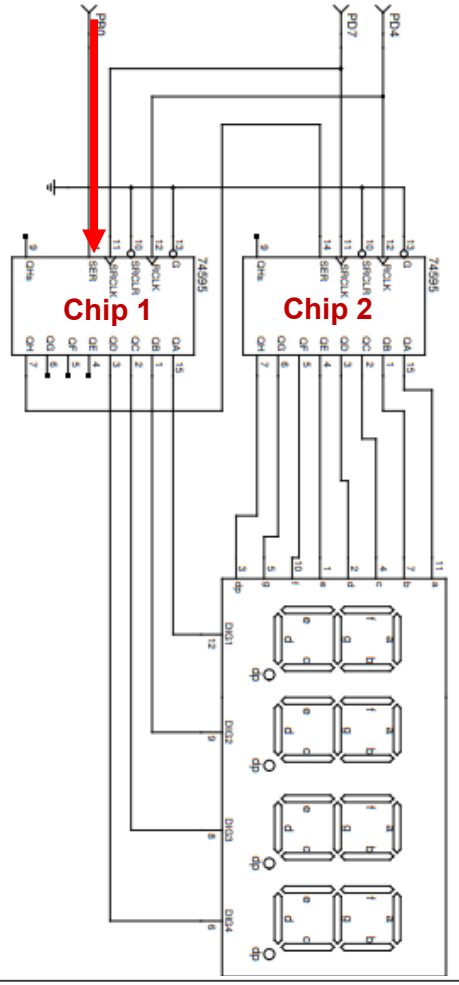


Chip 1								Chip 2							
QA	QB	QC	QD	QE	QF	QG	QH	QA	QB	QC	QD	QE	QF	QG	QH
f	g	dp													

Showing a single character

AT EACH 0 -> 1 TRANSITION OF PD7, A NEW BIT IS CLOCKED IN

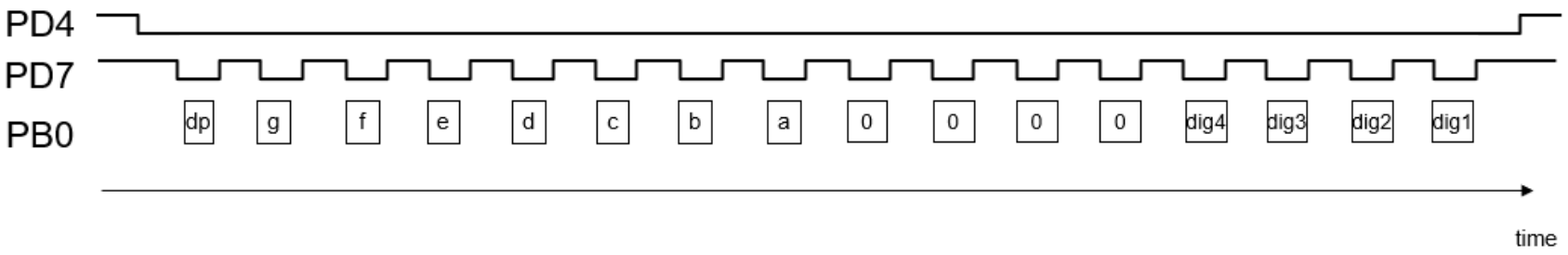


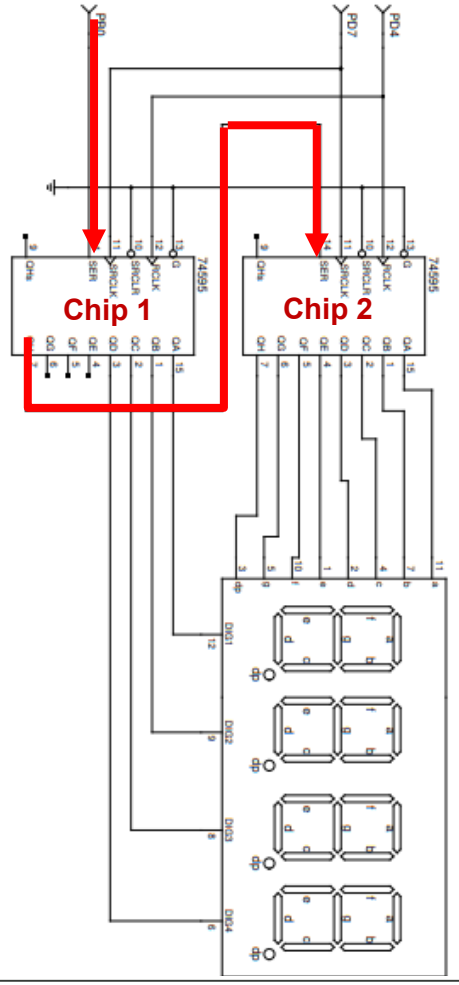


Chip 1								Chip 2							
QA	QB	QC	QD	QE	QF	QG	QH	QA	QB	QC	QD	QE	QF	QG	QH
e	f	g	dp												

Showing a single character

AT EACH 0 -> 1 TRANSITION OF PD7, A NEW BIT IS CLOCKED IN

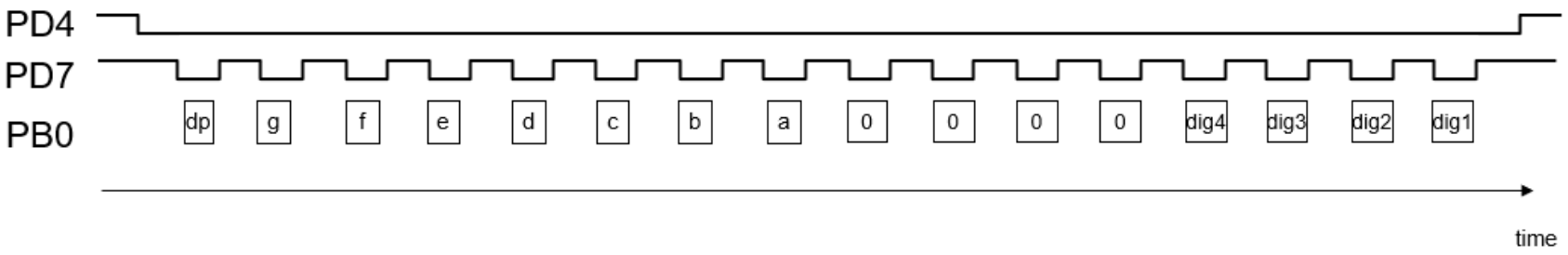


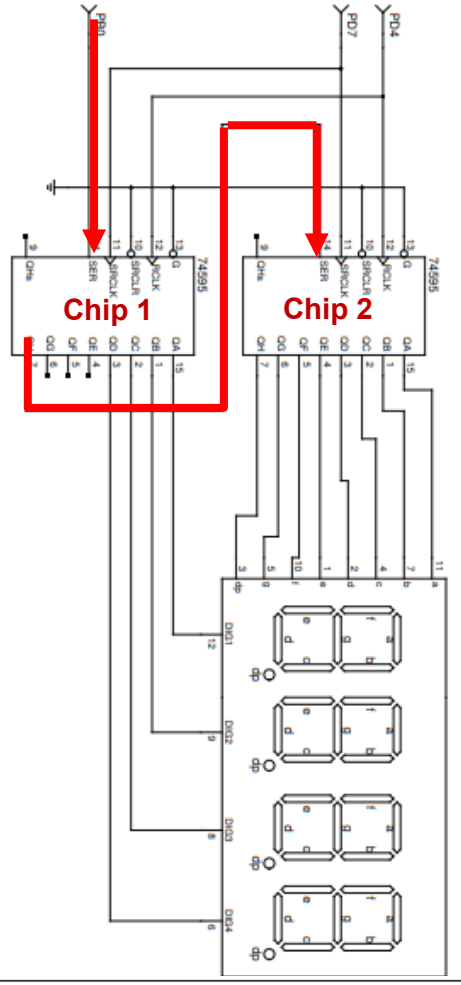


Chip 1								Chip 2							
QA	QB	QC	QD	QE	QF	QG	QH	QA	QB	QC	QD	QE	QF	QG	QH
0	a	b	c	d	e	f	g	dp							

Showing a single character

AT EACH 0 -> 1 TRANSITION OF PD7, A NEW BIT IS CLOCKED IN

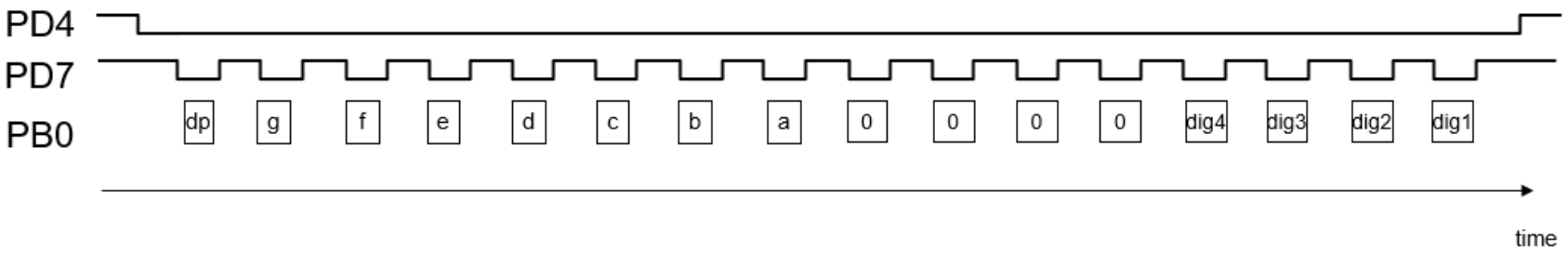


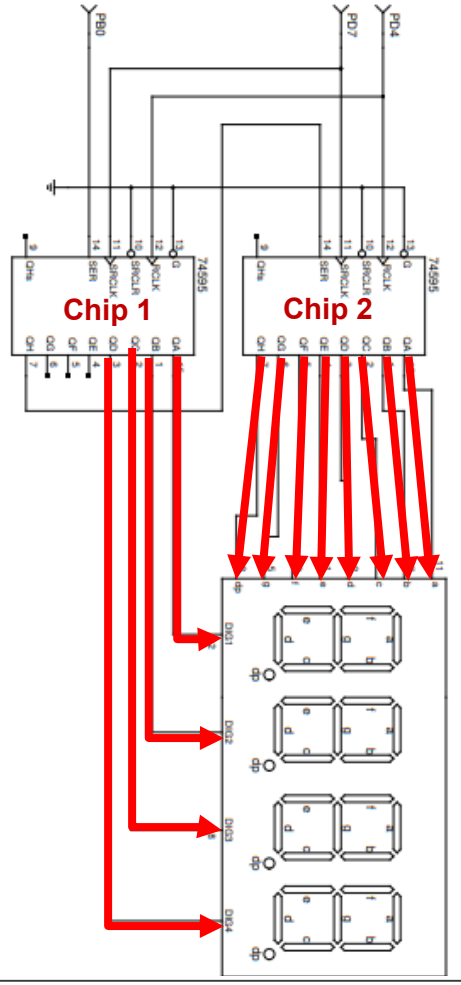


Chip 1								Chip 2							
QA	QB	QC	QD	QE	QF	QG	QH	QA	QB	QC	QD	QE	QF	QG	QH
dig1	dig2	dig3	dig4	0	0	0	0	a	b	c	d	e	f	g	dp

Showing a single character

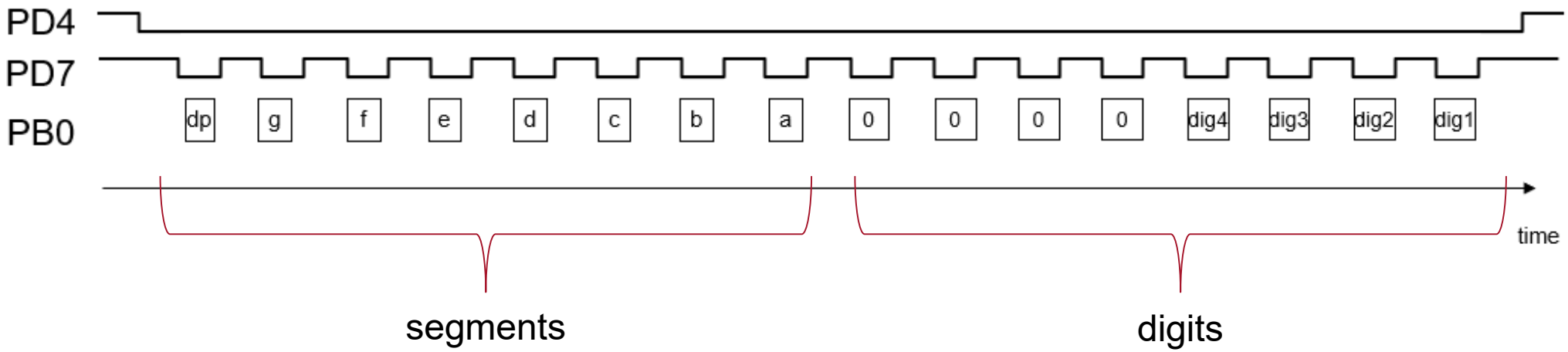
PD4 GOES HIGH TO LATCH TO DISPLAY





Chip 1								Chip 2							
QA	QB	QC	QD	QE	QF	QG	QH	QA	QB	QC	QD	QE	QF	QG	QH
dig1	dig2	dig3	dig4	0	0	0	0	a	b	c	d	e	f	g	dp
dig1	dig2	dig3	dig4	0	0	0	0	a	b	c	d	e	f	g	dp

Showing a single character




```
// send the 8 bits of data in segments (top bit first)
// then the 8 bits of data in digits (top bit first)
void sendData(uint8_t segments, uint8_t digits) {
    // TODO
}
```

Showing four digits

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```
char digits[4];

void showDigits() {
    for (int i = 0; i < 4; i++) {
        sendData(segmentMap(digits[i]), (1 << i));
    }

}
```

State Machines

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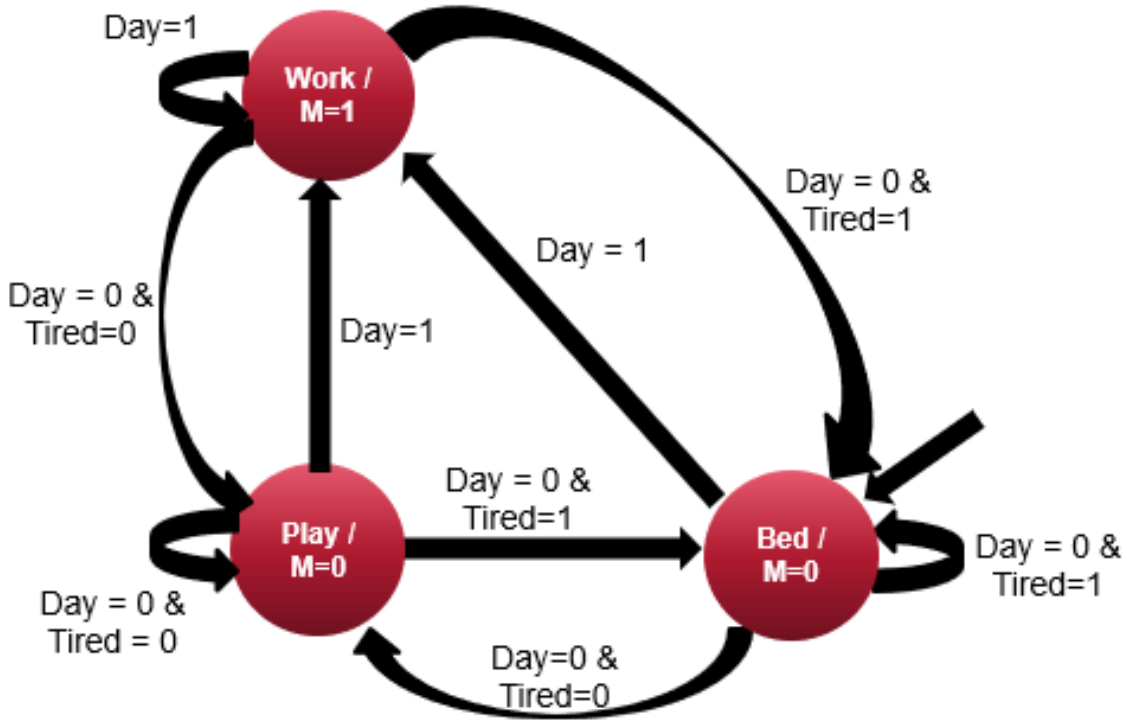
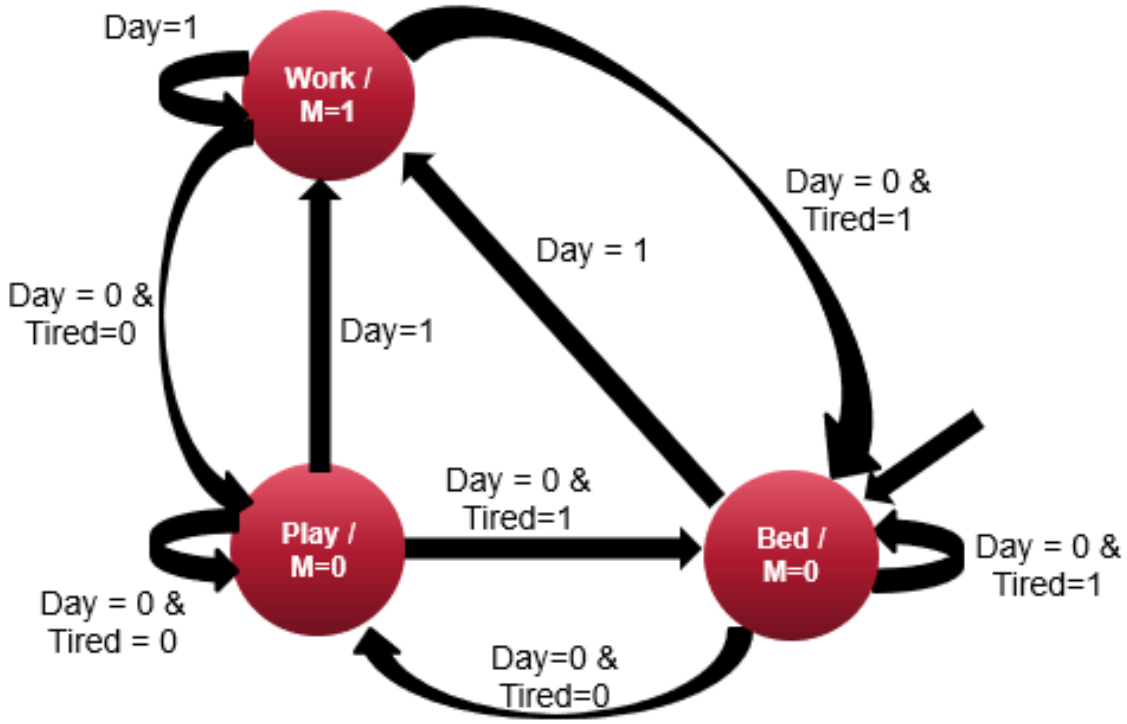
- Is a model describing the behaviour of a system as a set of states
  - A system can only be in one state at any time
  - Transition between states is dependent on the current state and the inputs to the system
- We can describe the relationship between states and their transitions via diagrams, equations, or tables
  - For this unit, you will be required to document the design of your system using:
    1. State transition diagrams
    2. State transition tables

State Transition Diagram



- Pictorial representation that is easy to follow
- Shows relationships between the states of a system

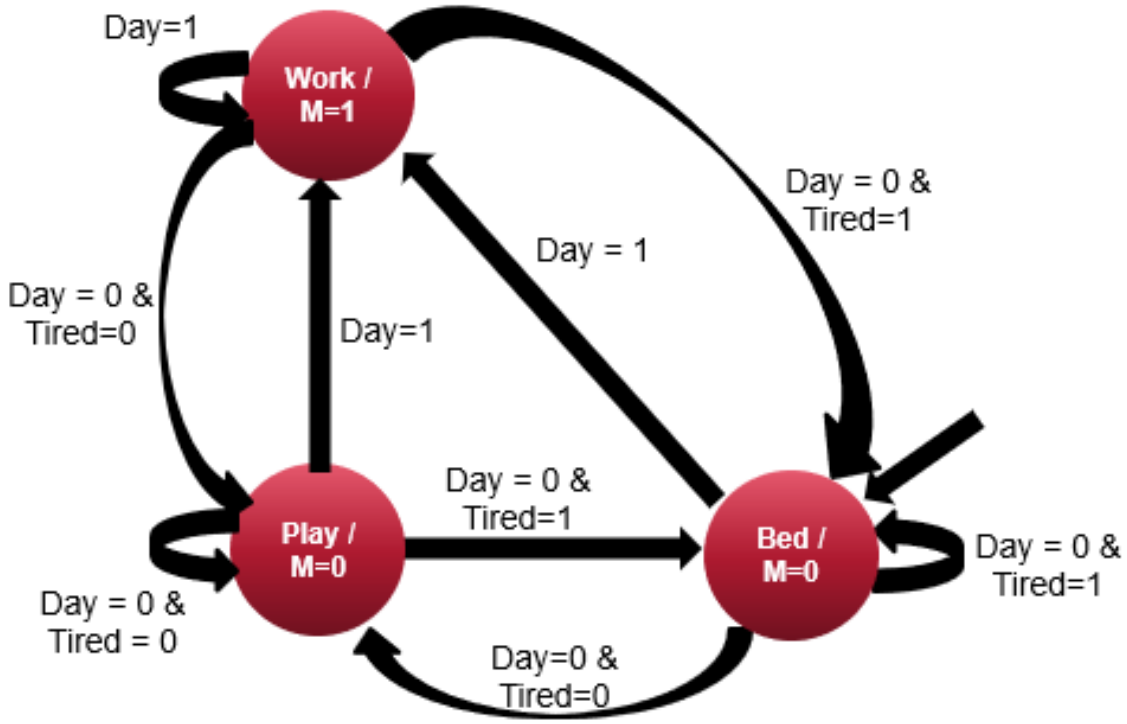
State Transition Table



- Easy way to ensure all possible inputs to a state are accounted for

Inputs		Current State	Next State	Output
Day	Tired			M
0	0	Work	Play	1
0	1	Work	Bed	1
1	0	Work	Work	1
1	1	Work	Work	1
0	0	Play	Play	0
0	1	Play	Bed	0
1	X	Play	Work	0
0	0	Bed	Play	0
0	1	Bed	Bed	0
1	X	Bed	Work	0

State Diagram to Code




```
switch (current_state) {
    case Work:
        M = 1;
        if (Day == 0) {
            if (Tired == 0) {
                current_state = Play;
            } else {
                current_state = Bed;
            }
        } else {
            current_state = Work;
        }
        break;
    case Play:
        M = 0;
        if (Day == 0) {
            if (Tired == 0) {
                current_state = Play;
            } else {
                current_state = Bed;
            }
        } else {
            current_state = Work;
        }
        break;
    case Bed:
        M = 0;
        if (Day == 0) {
            if (Tired == 0) {
                current_state = Play;
            } else {
                current_state = Bed;
            }
        } else {
            current_state = Work;
        }
        break;
}
```

Design Process

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1. Identify the main states of the system
2. What events (inputs) causes the system to change states?
3. What outputs are produced at each state?
   - If output is complex (more than just on/off), leave as a subsystem and pass a control flag
4. Construct state diagram and table showing the relationship between inputs, states and outputs
5. Repeat steps 1-4 for subsystems identified in step 3
   - An input to this subsystem would be the control flag
6. Draw a system block diagram showing the relationship between subsystems
   - Connect subsystem blocks by showing signal flows
7. Identify resources needed to implement system
8. Write your code
   - For each subsystem, write as a function
   - Write the code for the system state diagram in the main loop

Minor Project

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DRAW THE STATE DIAGRAM AND CONSTRUCT THE STATE TRANSITION TABLE

Pass Specifications

Operation Requirements

The general operations of the stopwatch are as follows. The initial state of the stopwatch is 0 minutes, 0 seconds and 0 fractions (1/10th) of a second. The stopwatch should start counting upwards from its initial state when the start/stop button is pressed. While counting up, pressing the start/stop button will pause the count and the time the button is pressed should be displayed. Pressing the start/stop button again should resume the count. Pressing the reset button should reset the stopwatch to its initial state.

The 7-segment display will indicate the current time of the stopwatch. The time should be shown with the format M.SS.f, where the left-most digit shows minutes (M) passed, the middle two digits show the seconds (SS), and the right-most digit for fraction of a second (f). The dot (.) is the decimal point on the 7-segment display. In its initial state, the display should show 0.00.0.

Button S1-A1 is used to reset the stopwatch to its initial state.

- Pressing S1-A1 at any time should stop the count and reset the display.

Button S2-A2 is used to start or pause/stop the stopwatch.

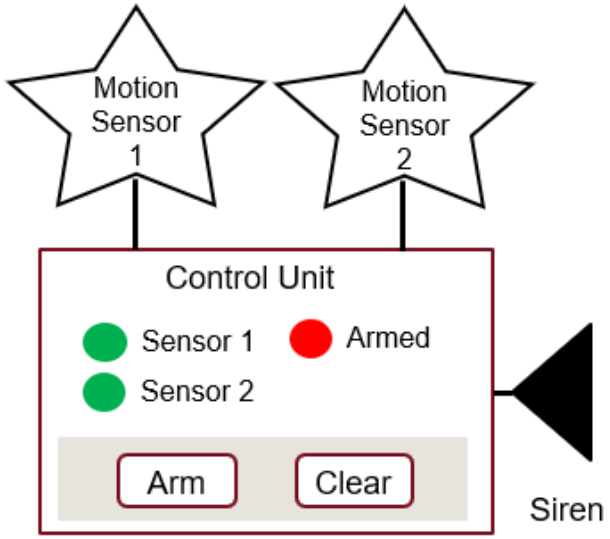
- If the stopwatch is not currently counting, pressing S2-A2 once will start the stopwatch counting up.
- If the stopwatch is currently counting up, pressing S2-A2 will pause the count and display the time when the S2-A2 was pressed.
- If S2-A2 is pressed and the display is showing a time other than 0.00.0, it should resume counting upwards.
- Pressing S2-A2 after a reset should start the count from 0.00.0.

LED D4 is used to indicate that the stopwatch has been paused.

- When the stopwatch is in its initial state, D4 should be off.
- When counting up, D4 should be off.
- When paused, D4 should be on.

Home alarm system

- System consists of:
  - Two motion sensors
  - Two buttons
  - Three status LEDs
  - Alarm siren



- The system should start with the alarm disarmed, and all LEDs and siren are off.
- When one of the motion sensors is triggered, the corresponding LED should light up and remain active for as long as motion is detected.
- To arm the system, the user should press the Arm key. This will put the system into the triggered state. During the triggered state, the Armed LED should flash at a rate of 1 Hz. The triggered state lasts for 5 s, after which the system will move into the armed state. In the armed state, the Armed LED should be continuously lit.
- During the armed state, if either of the motion sensors are triggered, it should set off the siren after a 5 second delay. The siren should sweep through frequencies 400 to 2000 Hz every two seconds.
- To stop the siren or to disarm the system, a user should press the Clear button.